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THE TRACTIVE RESISTANCE OF A 28-TON ELECTRIC CAR

BY
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CONTENTS

THE TRACTIVE RESISTANCE OF A 28-TON ELECTRIC CAR.

I. Introduction.

1. *Purpose.*—Three series of tests have been conducted by the Railway Engineering Department of the University of Illinois to determine the resistance offered to the motion of a 28-ton electric interurban car running on straight, level track, in still air at uniform speed; and to ascertain the relation existing between that resistance and the speed of the car. The first part of this bulletin describes the purpose, methods, and final results of the tests, but all details not essential to an understanding of the general methods and results are excluded. In the three appendices details are given concerning the apparatus, the methods of calculation, the test data, and the intermediate results.

2. *Definition of Terms.*—By the terms "resistance," "train resistance," and "car resistance" used in this bulletin is meant the number of pounds of tractive effort required at the rims of the driving wheels for each ton of train or car weight, to keep it moving at uniform speed on straight level track in still air. Such resistance data is employed in determining railway motor capacity, power consumption, and possible schedule speeds of a car or train of cars.

3. *Acknowledgments.*—The interest and co-operation of the officials of the Illinois Traction System have made it possible to carry out these tests over the lines of that road, and members of the Railway Engineering Department staff who have been concerned with this investigation thoroughly appreciate such interest and assistance.

The tests were planned by Professor Edward C. Schmidt, in charge of the Department of Railway Engineering, and they have been carried out under his general direction and supervision. He has also directed the work of the final computations, and reviewed the manuscript of the report. The tests of groups A and B were made under the direct supervision of Mr. Edgar I. Wenger, formerly Associate in the Department of Railway Engineering, and the preliminary calculations for these tests were made under his direction. The tests of group C and their preliminary calculations were made with the assistance of Mr. Daniel C. Faber, formerly a Research Fellow in the Engineering Experiment Station.

II. Summary.

Eighteen tests made on selected sections of tangent track are described. The track upon which the tests were made is of good construction, such as one would expect to find on the better grade of interurban electric railways. The weather during the tests was generally fair. The average temperature was not below 25° F., and the wind velocity did not exceed 26 miles per hour. The test car used is described in detail in Appendix I.

The general plan was to run the test car backward and forward over the chosen track section at a variety of speeds, but maintaining approximately the same constant speed during each pair of opposing runs. The tests comprise in all 269 resistance determinations of which 131 have been calculated from runs during which the wind opposed the motion of the car, 130 from runs during which the wind helped the car, and 8 from runs made when no wind was blowing. During the two tests of group A, comprising 45 resistance determinations, opposing runs have been separated by a considerable time interval during which wind and weather conditions might change; but through changes made in the method of making the tests, opposing runs for the remaining tests have been separated by a small time interval.

Each test, consisting of a number of "runs," resulted in a number of values of average net car resistance which have been plotted with the corresponding average speed, giving diagrams such as Fig. 3. Through the two groups of points representing the results of runs in opposing directions, curves have been drawn between which a final mean curve has been decided upon. By this method wind resistance has been eliminated as nearly as may be from the results. The curves thus determined have been accepted as the results desired from the individual tests and have been grouped in Fig. 1. A final mean curve has been drawn there and repeated as Fig. 2, which represents the average relation between resistance and speed for all the tests.

The results of the individual tests are shown in Figs. 10 to 19 and Tables 3 to 12, inclusive, in Appendix III. The final results of the investigation are presented in Fig. 1, Table 2, and in formulae 1 and 2, page 20.

It is believed that Fig. 1, Table 2, and formulae 1 and 2 provide expressions for the mean relation between the speed and the resistance of the car to which these tests apply, when it runs on tangent level track of good construction, at uniform speed, and in still air. The

greatest variation from these mean values under these conditions was about 9 per cent.

If application is made of these results to predict the resistance of any car of similar design and weight it should be borne in mind that the results apply to tests made with a car whose running-gear was in excellent condition, and that the tests were run in weather when the temperature was above 25° F.

III. Means Employed in Conducting the Tests.

4. *The Electric Test Car.*—The data for this report have been obtained by means of the electric test car belonging to the Railway Engineering Department of the University of Illinois. It is a standard 45-foot interurban car of the double end type, weighing, complete with equipment, 55 150 pounds, subject to correction on account of changes in the equipment at different times. The cross sectional area of the car body and trucks is 90 square feet.

The motor equipment consists of four 50-horsepower, axle mounted, number 101-D Westinghouse direct current motors, geared to the axle in the ratio of 22 to 62. The Westinghouse unit switch system of multiple control is used.

The trucks, which are of the C-60 type of the Standard Motor Truck Company, are placed 23 ft. 3 in. between centers and have a wheel base of 6 ft. 4 in. The wheels are 33 in. in diameter and have the standard Master Car Builders' tread and flange, and the journals conform to the 4¼ in. × 8 in. standard of the same association. A more complete description of the car will be found in Appendix I.

5. *The Recording Apparatus.*—By means of the apparatus within the car a continuous graphical record of current, voltage, speed, time by 5 second intervals, distance traversed, brake cylinder pressure, and location on the road may be kept. These records are drawn upon a chart 40 inches wide which is made to pass under the recording pens at a rate proportional to time or distance. Other data taken during this investigation, but not recorded upon the chart, are described on page 11. Fig. 9 shows a copy of a portion of the chart from test 121. The transverse lines which mark one of the sections selected for calculation and some of the explanatory lettering do not appear on the original record, and the records as shown in Fig. 9 are grouped more closely together than on the original chart. A more complete description of the recording apparatus is to be found in Appendix I.

6. *The Track.*—This investigation was carried out on the tracks

of the Illinois Traction System between Danville, Urbana, Champaign, Decatur, and Springfield—a single track line of good construction over which an hourly service is maintained between the points named.

That part of the line between Danville and Urbana, 32 miles in length, was laid during 1903 and 1904 with 70-pound A. S. C. E. section rails except for 9 miles near Urbana, where 60-pound A. S. C. E. 1901 section rails were in use at the time these tests were made. All rails were laid on oak cross-ties spaced about 24 inches between centers and ballasted with gravel and cinders. This track had between 2 and 3 years in which to become settled before the tests were started. The track between Champaign and Decatur was laid in 1906 and 1907 with 70-pound A. S. C. E. section rails laid on oak, elm, and chestnut cross-ties spaced about 24 inches between centers and ballasted with gravel. When tests were made over this track it was well settled and in first-class condition. The line between Decatur and Springfield was laid in 1905 and is in all respects similar to that between Champaign and Decatur, except that part of the track is ballasted with cinders.

A survey of the Danville-Urbana line was made by the Railway Engineering Department of the University immediately preceding these tests and the results expressed in a profile drawn to a scale of ¼-inch to 100 feet. Elevations were taken on the north rail to 0.1 ft. at stations 300 feet apart, and turning points were taken at every fourth station where levels were read to 0.01 ft. The exact distances between all trolley line poles were recorded and incorporated in a table from which all distances, such as those between section limits, were determined.

For the purpose of this investigation certain long sections of comparatively level and well ballasted tangent track on the Champaign-Decatur-Springfield line were selected and surveyed by the Railway Engineering Department of the University. The results of these surveys were expressed in profiles, drawn to a scale of ¼-inch to 100 feet, which were used in making the calculations.

IV. Test Conditions and Methods of Test.

7. *Test Conditions.*—The tests were all run during moderate weather. With four exceptions they were made on clear days only and on dry track. Data in regard to wind velocity and direction were obtained from United States Meteorological stations at Urbana, Springfield and Peoria, and during one group of tests, designated as group "C," these data were supplemented by wind determinations made by means of a portable wind vane and anemometer set up beside the test track. Tables 3 to 12 inclusive in Appendix III show that the approximate

average wind velocities prevailing during the tests varied from 0 to 26 miles per hour. The lowest average air temperature recorded during any test was 25° F., and the highest recorded temperature was 80° F.

TABLE 1

A SUMMARY OF TEST CONDITIONS

1	2	3	4	5	6	7
				Approximate Wind Data		
Test No.	Weight of Car and Load	Approximate Average Air Temperature	Rail Condition	Average Direction	Average Velocity	Average Velocity Parallel to Test Track
	Pounds	Deg. F.			M. P. H.	M. P. H.
15–16	56 600	40	Dry	S. of W.	7.2	7
23–24	56 250	70	Dry	S. W.	15.1	11
73–74	56 650	40	Wet	N. of W.	10.0	9
77–78	56 800	40	Dry	N. W.	12.0	12
91–92	56 350	45	Dry	S. W.	26.0	24
95–96	56 350	65	Dry	N. W.	16.0	15
109–110	56 950	55	Wet	S. W.	18.0	13
111–112	56 350	55	Wet	S. W.	18.0	13
113–114	56 200	55	Dry	S. W.	10.0	7
117–118	56 200	25	Wet	S. W.	12.0	9
119–120	56 750	45	Dry	W. of S.	3.5	2
121–122	56 750	30	Dry	E. of N.	3.0	2
123–124	56 750	30	Dry	S. E.	4.0	3
125–126	57 350	35	Dry	S. W.	15.0	10
127–128	57 500	25	Wet		0	0
129–130	57 350	65	Dry	S. E.	15.0	10
141–142	57 800	40	Dry	W.	3.8	3
153–154	57 900	60	Dry		0	0

The track sections selected for the tests are all straight and they vary in length from 250 to 10 000 feet. The majority of the tests were made on sections varying in length from 1000 to 1500 feet. Other requirements to be met by the sections were that the grade should be comparatively light and uniform, and that the track should be well ballasted and in good condition. While on the road the car was always in charge of a regular train crew provided by the Illinois Traction System.

8. *Calibrations.*—Preceding the commencement of the tests, all instruments were calibrated and at intervals during the investigation check readings were taken by means of indicating instruments in the same circuits as the recording instruments. Wherever possible, the results of these calibrations were expressed in the form of equations or tables as well as curves, and in making the calculations one of the two former was used in place of taking readings from curves. Owing to changes made in the apparatus during the tests, more than one calibration was necessary for several of the instruments.

9. *General Plan of the Tests.*—The test car records give quantities from which the gross resistance offered to motion of the car over a given section of track must first be calculated. The result desired from each run is that element of gross resistance which is always operating to retard a moving car or train; namely, the net resistance on straight and level track, at uniform speed, in still air. The other elements, one or more or none of which may be acting with the net resistance to form gross resistance, are: Resistance due to grade, resistance due to acceleration, curve resistance, and wind resistance (as distinguished from still air resistance). The tractive effort consumed by grade and acceleration may readily be determined by calculation, and the tests herein reported were so planned as to eliminate the two remaining elements. Curve resistance has been eliminated by selecting for calculation only those sections of chart made while the car was running on straight track. It is thought that by the procedure explained below the effect of wind resistance upon the final result has been reduced to a minimum.

The car was first run in one direction and then in the other over a given track section, at as nearly uniform speed as possible. A series of such runs, made at speeds varying through as wide a range as possible. constituted a test. Each run results in a value of average net car resistance which, when plotted with the corresponding average speed, becomes one point on a resistance-speed plot such as is shown in Fig. 3. By the to and fro motion of the car the wind alternately helps and opposes its motion and thereby decreases or increases its resistance. The resistance values from each test therefore fall into two groups, one of which represents values of resistance running with the wind, while the other represents values running against the wind.

In the figures, those points applying to runs with the wind are shown as solid dots, while the points applying to runs against the wind are shown as open circles. By methods which are described on pages 13 and 14, a mean curve has been drawn in each figure which represents the values of resistance with the influence of wind eliminated. These mean curves have been accepted as the desired resistance curves for the individual tests and have been grouped together as Fig. 1. An average curve obtained from this group, by the method described on page 20, has been repeated as Fig. 2 and accepted as the final curve of resistance for this 28-ton electric car under the conditions described.

As a result of slight variations in the methods of conducting the tests, they fall into three groups designated as A, B and C, which differ in the effect their conditions have on the assumptions regarding wind

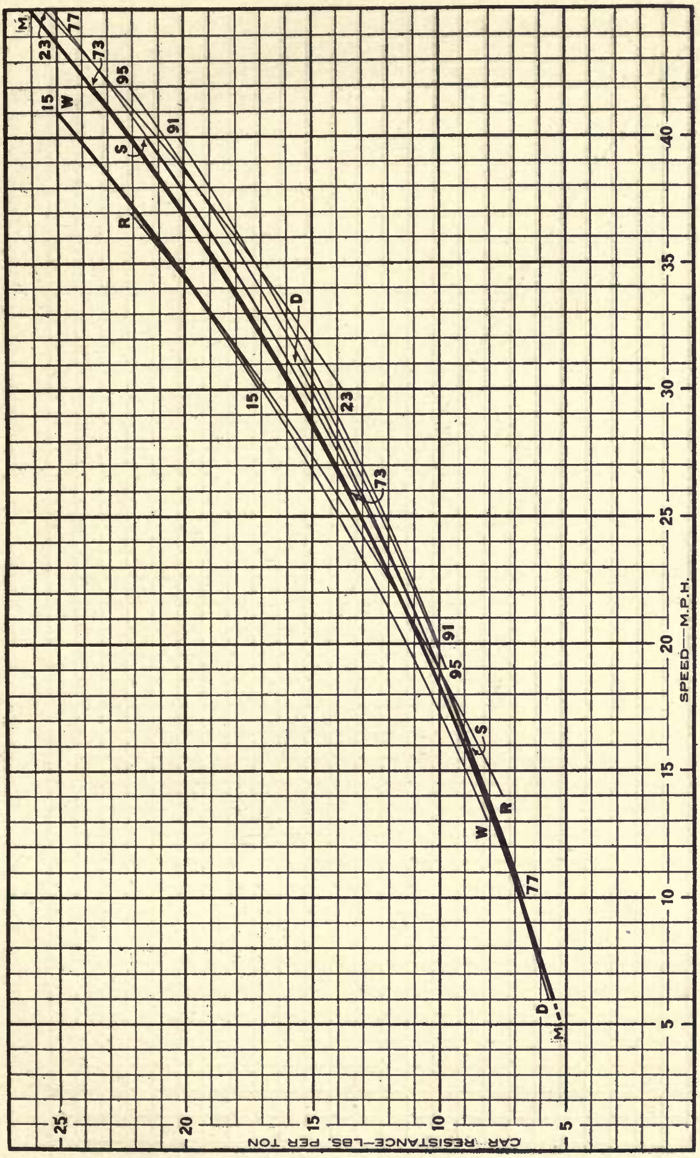

FIG. 1. THE RELATION OF RESISTANCE TO SPEED FOR ALL THE TESTS.

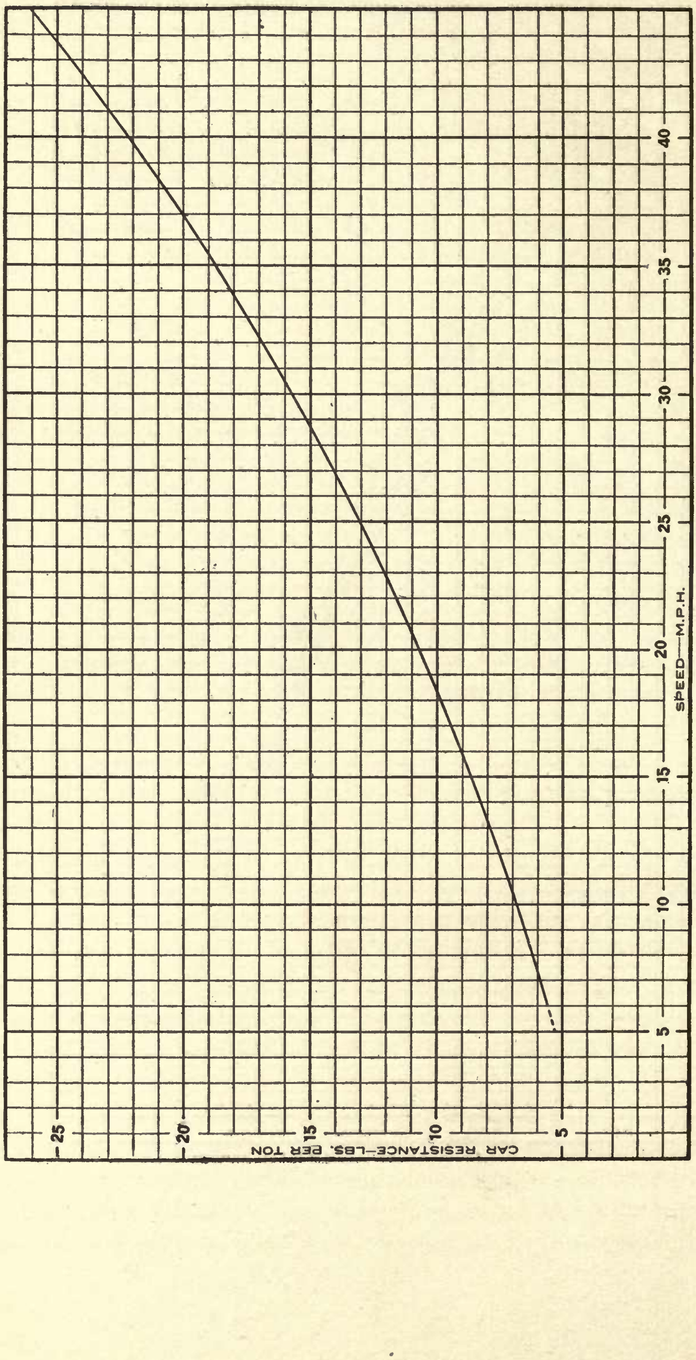

FIG. 2. THE MEAN RELATION BETWEEN RESISTANCE AND SPEED FOR ALL THE TESTS.

resistance, in the methods of obtaining certain data, and in the speed range.

10. *Group A.*—Those tests comprised in group A were through runs from Urbana to Danville, 32 miles, and return. During any test of this group only one set of opposing runs was made on any given section and such opposing runs were separated by a considerable time interval, since it took over an hour to run from Urbana to Danville or to return.

Test 23-24 is characteristic of this group. The results are shown in Table 4 and Fig. 11, which has here been repeated as Fig. 3. The recording apparatus was kept in operation throughout the trip and the following data recorded graphically upon the chart:

a. Current used by the motors.
b. Trolley line voltage.
c. Speed of the car by electrical recorder. (See App. I.)
d. Time by 5 second intervals.
e. Location upon the road.
f. Distance by 50 ft. intervals.
g. Brake cylinder pressure.

The following data were taken but not recorded graphically:

h. Average wind velocity and direction.
k. Air temperature.
l. Rail condition.
m. Weight of car and load.

Item *e,* the location of the car on the road, by means of which it is possible to correlate any position of the car with the profile of the road, was made by marking upon the chart the position of numbered trolley line poles, stations, or other markers as they were passed by a given point on the car. The brake cylinder pressure, item *g,* was recorded in order to make it possible to distinguish and to avoid those periods during the tests when the brakes were applied. Data regarding average wind velocity and direction, item *h,* were obtained from United States Weather Bureau Stations. Fig. 9, page 27, has been reproduced from a tracing of a portion of the chart for test No. 121.

Sections of chart were selected for calculation by comparison of the profile and chart as described in Appendix II. In general, the requirements to be met by the chosen chart sections are that the car shall be running on straight track, that no brake applications be made, that there be no heavy grades between the section limits, and that there be no considerable voltage, current or speed variation. They were chosen

so that the speed range covered was as large as possible and so that the number of sections from an east bound trip (Urbana to Danville) would be balanced by the same or approximately the same number from the west bound trip. In this way the number of resistance determinations made from data taken during runs against the wind were balanced by an approximately equal number from runs with the wind. From test 23-24, for example, fourteen sections were chosen from the east bound and thirteen from the west bound trip.

In all the tests reported in this bulletin the variations in speed in passing the track sections have exceeded 2 miles per hour in only 28 per cent of the total number of resistance determinations, and in only 24 cases out of 269 has this speed variation exceeded 5 miles per hour. The maximum variation over any section was 9.95 miles per hour.

Each of the chosen chart sections has afforded, through calculations made with the data there recorded, a value of average net car resistance. The calculations are described in Appendix II. The steps in the process are here stated briefly. The average values of current and voltage were found for each section by determining the average ordinates of the curves. This data, with the time required for the car to pass the track section, and the efficiency of motors and gears at the above current and voltage, made it possible to calculate the energy in foot pounds delivered by the current to the driving wheels of the car. The energy thus determined was then corrected for grade and acceleration resistances, thereby giving the net energy absorbed by car resistance, from which the average net car resistance in pounds per ton was readily obtainable. In order to make the grade correction it was first necessary to determine the elevation of the center of gravity of the car as it entered and again as it left the track section. The correction for acceleration was calculated from the speeds determined by the heights of the speed curve at the points of entrance and exit. For this purpose determinations were made of the force required to produce accelerations in the rotation of the revolving parts as well as of the force required to produce the acceleration in the motion of translation of the car as a whole.

From each test a number of chart sections have been chosen and, as has been stated, each section has resulted in a value of average net car resistance which has been plotted with the corresponding average speed, thereby giving diagrams such as Fig. 3. Due to the method of selecting chart sections from opposing runs, the points on each such resistance-speed plot fall into two groups as previously explained. The

numbers beside the points are the item numbers from the tables in Appendix III.

In drawing the curve to represent the results of the individual tests the two groups of points were first considered separately and a curve drawn for each. Thus, for example, curve *A*, Fig. 3, was drawn to represent the relation between resistance and speed for all the runs of test 23-24 during which the wind opposed the motion of the car, and curve *B* for the opposite condition. In order to draw these curves the plotted points were considered as being subdivided into a number of smaller groups, for each of which averages of speed and resistance were determined and plotted. Through the points representing these averages

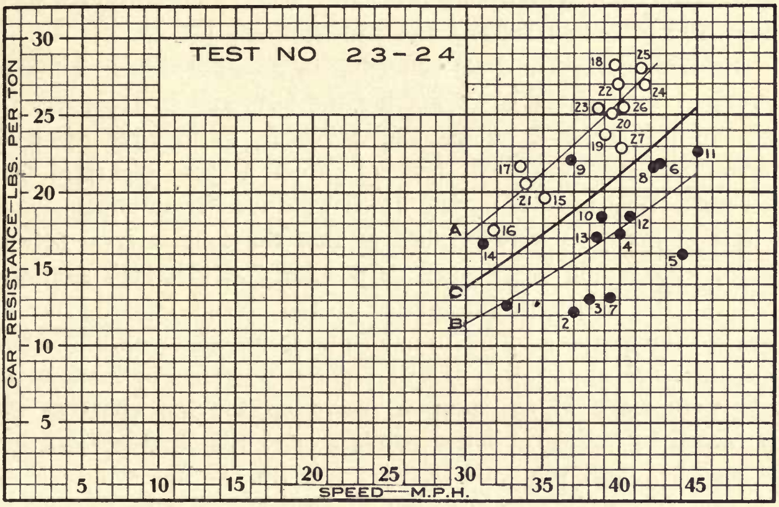

FIG. 3. THE RELATION OF RESISTANCE TO SPEED FOR TEST 23-24.

the curves were drawn. The groups of points were chosen so that the resulting average points would be distributed at about equal intervals throughout the speed range. The next step was to draw a mean curve such as *C*, Fig. 3, which would represent the relation existing between resistance and speed in still air. Since investigations indicate that the resistance offered by wind varies with the square of the speed, an arithmetical mean would not satisfy the conditions. Accordingly, an equation taking account of this fact has been derived (see Appendix II, page 34) and by means of it the ordinates of points on the mean curve have been calculated from the ordinates of the *A* and *B* curves at the same speed. The mean curves drawn by this method agree much more closely

than do those curves drawn as arithmetical means between the *A* and *B* curves, and it has consequently been assumed that the method used has resulted in curves more accurately representing the resistance in still air than would have been obtained by using the arithmetical means.

The six curves thus obtained from tests of groups A and B, and the four from group C which were drawn by another method, were then superimposed upon each other in order to determine the characteristic form, and the individual curves were then modified to conform to that general shape. The curves drawn in this manner have been accepted as the results desired from the individual tests.

In group A there are two tests, namely 15-16 and 23-24, comprising together a total of 45 resistance determinations. The results are shown in Figs. 10 and 11 and Tables 3 and 4 in Appendix III.

11. *Group B.*—The tests belonging in group B differ from those in group A in the method of making the tests and in the effect this change in method has upon the assumptions regarding wind resistance. Whereas opposing runs from tests of group A were separated by a considerable time interval during which wind conditions might change, the tests of group B were planned so that the time interval between opposing runs would be as small as possible. A well kept section of track 1495 feet in length and located on the Urbana-Danville line was chosen for this purpose. The limits of this section, between which there was a difference in elevation of 0.56 feet, were defined by markers and offsets were made in the location record on the test chart as they were passed by the car. These points located the chart section to be calculated for each run. During any test the car was run back and forth over this section at a variety of speeds, each pair of opposing runs being made at approximately the same uniform speed. Data exactly similar to that obtained during the tests of group A were taken during each run. The reasons enumerated on pages 11 and 30 for the rejection of any chart section apply also to the runs of this group of tests. Through calculations made in the same way as has been described for the previous group, each run has resulted in an average value of net car resistance for the average speed at which the car passed the track section. These have been plotted and curves drawn by the method described for group A.

There are four tests in group B, namely, 73-74, 77-78, 91-92 and 95-96. The results are given in Figs. 12 to 15 and Tables 5 to 8, inclusive, in Appendix III.

12. *Group C.*—The principal points of difference between the tests of this and of preceding groups lie in the method of obtaining certain data, in the plan of grouping the results from two or more tests made on the same track section, and in the method of drawing the final curves.

Track sections, each comprising two or more tangents varying in length from 338 to 1320 feet, were chosen so as to meet the same requirements as those prescribed for the tests heretofore described. They have been designated by letters as follows:

D: Approximately 2680 feet long, located near Urbana on the Danville-Urbana line.

W: About 3700 feet in length, located near White Heath on the Champaign-Decatur line.

S: About 4100 feet long, located near White Heath on the Champaign-Decatur line.

R No. 1: Approximately 3000 feet long, located near Riverton on the Decatur-Springfield line.

R No. 2: About 4500 feet in length, located near Bement on the Champaign-Decatur line.

During each test the car was run back and forth over the chosen track section, as during the tests of group B, so that opposing runs were separated by a small time interval as in that group. Throughout each run the recording apparatus was kept in operation and data taken which were similar to those obtained during the tests that have been described, although the method of taking them was in some cases different. Changes made in the instrument equipment were as follows:

For the tests of groups A and B line voltage was recorded; but during the tests of group C connections were changed so that the record was that of voltage across the terminals of one motor. This change was made to facilitate calculations.

A Boyer mechanical speed recorder was installed in addition to the electric recorder described in Appendix I, and the record made by it has been used in the calculations. Both instruments were driven from the same shaft.

A portable windvane and anemometer were used during these tests to determine wind direction and velocity. These instruments were set up beside the test track and readings were made at intervals during the tests. By this means much more accurate determinations were made than could be obtained from the Weather Bureau reports.

It was found upon the completion of the tests of groups A and B

that a low enough speed range had not been obtained and steps were therefore taken to supply this deficiency on subsequent tests. Two water rheostats were connected in the trolley circuit for the control of the motor voltage and the speed was held as nearly as possible at a constant predetermined value by the operator, who had for his guidance an ammeter in series with the speed-recording ammeter.

From the record of each run made over the test track, chart sections were chosen for calculation in accordance with the requirements stated on page 14 to conform to the characteristic shape. The resistance curves groups A and B. Each such chart section has resulted in one point on a resistance-speed plot such as Fig. 16, Appendix III. The results of all tests made on any given track section have been grouped together as, for example, track section D, on which tests 109-110, 111-112 and 113-114 were made. Inasmuch as the resistance-speed points in Fig. 16 have been derived from the results of tests made under somewhat different weather and wind conditions, it was found impracticable to draw the final curve in the same manner as for groups A and B. Consequently, in place of following the method described on page 13, the points on each resistance-speed plot, irrespective of the wind effect, were assumed to be divided into a number of groups, for each of which arithmetical averages of the values of speed and resistance were determined and plotted. These groups of points were chosen so that the resulting averages would be distributed at about equal intervals throughout the speed range. Through them the curve representing the relation between resistance and speed was drawn and later modified as described on page 14 to conform to the characteristic shape. The resistance curves thus derived, which are shown in Figs. 16 to 19 inclusive, have been accepted as the results desired from this group of tests.

It is recognized that this method of drawing the resistance curves is a deviation from the general plan followed for the preceding tests, but Fig. 1 shows that this deviation has brought about no greater variation of the individual curves from the mean curve *MM* than is found among those drawn as described on page 13. This may be accounted for by the fact that the wind velocities prevailing during the tests in question (see column 7, Table 1) were on the whole less than those prevailing during the preceding tests, and that consequently the resistance-speed points for runs with and against the wind were closely interwoven. Had the tests of group C lent themselves to the plan described on page 13, the curves with and against the wind would have

been quite close together, and the mean curves determined by the two methods would not have differed greatly.

It will be noted that the numbers of the tests here included are not consecutive. Some of the tests bearing the intervening numbers were made for other purposes, but a considerable number were made for the purpose of this investigation and were later discarded for various reasons. Of the latter the greater number were omitted because an insufficient number of runs were made over the track sections to accurately determine a curve. This was occasioned by the necessity of running the car on sidings to allow regular cars to pass. Others were discarded because it was impossible to choose a sufficient number of chart sections that would meet the requirements, and still others were in the nature of preliminary runs.

V. Results of the Tests.

13. *Results of the Individual Tests.*—The results of the individual tests are shown in the form of resistance-speed curves in Figs. 10 to 19 and Tables 3 to 12, inclusive, in Appendix III.

These tests, without exception, show a marked increase in resistance as the speed increases. The effect of wind resistance is clearly shown by a comparison of Figs. 10 to 15 inclusive, which have been derived from tests of groups A and B. For those tests during which a heavy wind alternately opposed and helped the motion of the car, the two curves, such as A and B (Fig. 3), drawn to represent the results of runs in opposite directions, are some distance apart, while for tests during which the wind was light these curves are quite close together. Figs. 15 and 10 illustrate this difference. Fig. 15 has been derived from test 95-96 during which the component of the average wind velocity parallel to the track was 15 miles per hour while Fig. 10 has been derived from test 15-16 during which that component was 7 miles per hour.

Had the wind velocity and direction remained precisely alike during all runs of a test, then the components of the wind velocity parallel to the track would have been of like value and the process of drawing the mean curve for the test would be valid in so far as the fundamental assumption underlying this process is in itself valid. The wind velocity and direction did not remain precisely constant during all runs of a test, however, and the resulting mean curves are consequently slightly in error. No method of eliminating this error or of evaluating it has presented itself.

The component of the wind velocity which is perpendicular to the test track increases gross resistance, irrespective of the direction in which the car is running, by pressing the flanges of the car wheels against the head of the rail, thereby increasing the frictional resistance. No method has been found for evaluating its effect upon the final resistance values and it is therefore included in the accepted results. Obviously it is one cause for the variations among the resistance curves as well as for the variations among the individual resistance-speed points.

Due in part to the reasons just mentioned, the points in any of the resistance-speed plots may vary considerably from the final mean curve for that test. The maximum variation of any point from the mean is approximately 90 per cent. Any comparison of variations from the mean made to determine the agreement of the results among themselves should, however, be confined to the results obtained from runs in one direction only. Such a comparison among the resistance determinations for tests of groups A and B shows variations which, though large in some cases, are not unusual for this class of experimental work. The maximum variation from the mean for the first two groups of tests occurred during test 23-24 (Fig. 3). Point 9 varies 42.5 per cent from mean curve *B*. The next largest variation is 24 per cent, while the average is much less than that. A very small percentage of this variation may be due to accumulated errors in instruments or in the calculations, although all reasonable precautions have been taken to avoid such errors. Each step in the process of making the calculations and producing the tables and curves has been duplicated at a different time and usually by a different person, and in all cases where the calculated value of resistance differed greatly from the mean all calculations leading thereto were repeated. The influence of such variable and uncontrollable elements of net resistance as flange friction, journal friction, instantaneous changes in velocity and direction of the wind, and changes in the lubrication of bearings and gears, is believed to be sufficient to account for the differences shown in the curves here presented. The variations of the points in Figs. 16 to 19, inclusive, are chargeable to the differences in the test conditions that are represented on those resistance-speed plots as well as to the above-mentioned causes.

14. *Results of All the Tests.*—The six resistance curves for the individual tests of groups A and B, and those representing the results obtained on the four track sections of group C, have all been brought together in Fig. 1.* In view of the number and character of the elements

*Each curve has been marked with the test number or letter corresponding thereto.

of net resistance that can not be controlled, the differences among the curves there shown are not greater than might be expected. For speeds up to 20 miles per hour the maximum variation among the resistance values from the different curves is about 13 per cent, between 20 and 30 miles per hour this variation is approximately 17 per cent, while above 30 miles per hour it approximates only 20 per cent.

TABLE 2

VALUES OF RESISTANCE AT VARIOUS SPEEDS, DERIVED FROM THE FINAL CURVE AND THE CURVES FOR THE INDIVIDUAL TESTS. THIS TABLE PROVIDES THE CO-ORDINATES OF THE CURVES IN FIGURE 2.

Speed — Miles Per Hour	Car Resistance—Pounds Per Ton										
	Final Mean Curve	Test 15–16	Test 23–24	Test 73–74	Test 77–78	Test 91–92	Test 95–96	Tests on Section D	Tests on Section W	Tests on Section S	Tests on Section R
5	5.25										
6	5.52							5.65			
7	5.81										
8	6.12										
9	6.48										
10	6.80				6.62			6.87			
11	7.12										
12	7.50										
13	7.87								8.12		
14	8.25										7.55
15	8.62				8.48			8.62	9.00		8.02
16	9.05									8.75	
17	9.48										
18	9.87										
19	10.32						9.75				
20	10.75				10.50	10.02	10.18	10.55	11.30	10.44	10.60
21	11.22										
22	11.66										
23	12.13										
24	12.62										
25	13.03				12.75	12.13	12.37	12.65	13.93	12.75	13.45
26	13.62			13.55							
27	14.12										
28	14.65										
29	15.22										
30	15.75	17.10	13.84	15.73	15.34	14.54	14.85	15.00	16.88	15.30	16.70
31	16.36							15.50			
32	16.90										
33	17.50										
34	18.12										
35	18.75	20.44	17.15	18.75	18.22	17.22	17.62		20.25	18.21	20.47
36	19.37										
37	20.04										22.13
38	20.75										
39	21.44										
40	22.13	24.20	21.00	22.16	21.45	20.25	20.75		24.15	21.50	
41	22.87	25.02							25.00		
42	23.66			23.68			22.12				
43	24.45										
44	25.26										
45	26.12		25.56		25.25						

The mean curve *MM* shown in Fig. 1 and reproduced as Fig. 2 has been drawn to express the average relation between resistance and

speed for all the tests. To determine this curve, the resistances corresponding to a given speed, say 10 m.p.h., were taken from the individual curves of Fig. 2 and averaged. In this process each resistance value was given a weight corresponding to the total number of resistance determinations represented by the curve from which it was taken. These averages were calculated at speeds varying by steps of 5 miles per hour and plotted in Figs. 1 and 2. Through them the mean curve *MM* has been drawn. The curve thus determined represents the final results obtained from this investigation. The values of resistance at various speeds have been determined from all the curves shown in Fig. 1 and they are presented in Table 2. The data there given are sufficient to accurately reproduce all the final resistance-speed curves.

The final results have also been expressed in the form of an equation which is given as formula 1. This equation makes it possible to calculate resistance values that do not vary more than one-half of one per cent from those obtained from the curve *MM*. In this formula R is the resistance expressed in pounds per ton and S is the speed in miles per hour.

$$R = 4 + 0.222\,S + 0.00582\,S^2 \ldots\ldots\ldots (1)$$

This equation has been modified as shown in formula 2 to take more definite account of air resistance. In formula 2, A is the cross-sectional area of the car expressed in square feet and W is the car weight in tons.

$$R = 4 + 0.222\,S + 0.00181\,\frac{A}{W}\,S^2 \ldots\ldots (2)$$

These formulae are the equations of a parabola which corresponds closely to the curve *MM*. In using these formulae care should be taken not to extend their use to speeds much beyond the limits of the curve *MM*.

15. *Discussion of the Final Results.*—The final results of this investigation are presented in Fig. 2, Table 2, and formulae 1 and 2, all of which express the mean relation between speed and resistance for the 28-ton car when running at uniform speed on tangent and level track of good construction, during weather when the temperature is not lower than 25° F., and when the wind velocity does not exceed about 26 miles per hour. The curve *MM* (Figs. 1 and 2) is an average of curves derived from ten individual tests that have been run under conditions which, though they differ somewhat, are not at all unusual. Notwithstanding this difference in test conditions, the maximum variation of the individual curves from the mean curve *MM* is only 12 per cent (see Fig. 1). With the exception of that portion of the curve for

test 23-24, which lies between 30 and 34 miles per hour, the maximum variation of the individual curves from the mean curve is only 9 per cent for all speeds above 30 miles per hour. At speeds below 30 miles per hour this variation is considerably less than 9 per cent. In other words, all curves from the individual tests lie within a narrow belt. All points within this belt may very properly be considered to represent a relation between car resistance and speed which is true under some usual conditions.

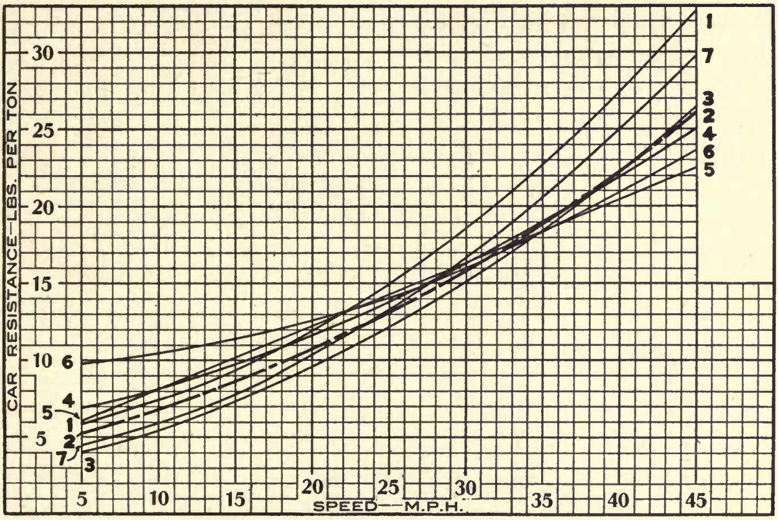

FIG. 4. COMPARATIVE DIAGRAM OF RESISTANCE-SPEED CURVES CALCULATED BY MEANS OF SEVEN FORMULAE APPLICABLE TO ELECTRIC RAILWAY CONDITIONS.

W = 28 TONS. A = 90 SQ. FT. N = 1.

1. DAVIS.
2. UNIVERSITY OF ILLINOIS.
3. SMITH.
4. BLOOD.
5. LUNDIE.
6. ARMSTRONG.
7. MAILLOUX.

If it is desired to estimate the resistance of any car which in weight and general design is similar to the car used during these tests, it is believed that the curve *MM* offers a basis for the prediction of such resistance, the accuracy of which will lie within the limits just stated; that is, it is believed that by the use of the curve *MM* net resistance may be predicted within about 9 per cent. Obviously, in using the curve for such a purpose the conditions surrounding these tests must be fully appreciated.

In addition to the expression given for the resistance in still air, the tables and curves in Appendix III provide information as to the excess resistance due to wind. They show that during moderate weather and for wind velocities up to 24 miles per hour which directly oppose the motion of the car, the resistance may exceed that in still air by as much as 70 per cent at speeds below 30 miles per hour, and by 50 per cent at speeds above 30 miles per hour.

16. *Comparison with Other Experiments.*—For purposes of comparison with the results of other investigations the following formulae are given, together with Fig. 4:

Davis[1] $$R = 5 + 0.13\,S + \frac{0.3\,S^2}{W}[1 + 0.1\,(N - 1)]$$

University of Illinois $$R = 4 + 0.222\,S + 0.00582\,S^2.$$

$$R = 4 + 0.222\,S + 0.00181\frac{A}{W}S^2.$$

Smith[2] $$R = 3 + 0.167\,S + 0.0025\,\frac{A}{W}S^2.$$

Blood[3] $$R = 6 + 0.13\,S + \left(0.0014 + \frac{0.35}{W}\right)S^{1.8}.$$

Lundie[4] $$R = 4 + 0.24\,S + \frac{4.8\,S}{W}$$

Armstrong[5] $$R = \frac{50}{\sqrt{W}} + 0.03\,S + \frac{0.002AS^2}{W}[1 + 0.1\,(N - 1)]$$

Mailloux[6] $$R = 3.5 + 0.15\,S + \frac{0.02\,N + 0.25}{N\,W}S^2$$

Notation:—R = Car resistance in pounds per ton.
S = Speed of the car in miles per hour.
W = Weight of the car in tons.
N = Number of cars in the train.
A = Effective cross-sectional area of the car body and trucks in sq. ft.

1. Street Railway Journal, 1904, v. 24, p. 1003.
2. Proc. Amer. Inst. Elec. Eng., 1904, v. 23, p. 696.
3. Proc. Amer. Soc. Mech. Eng., v. 24, p. 945.
4. Street Railway Journal, 1902, v. 19, p. 557.
5. Standard Handbook for Electrical Engineers, Section on Electric Traction, by A. H. Armstrong.
6. Proc. Amer. Inst. Elec. Eng., 1904, v. 23, p. 731.

APPENDIX I.

The Electric Test Car.

The electric test car, by means of which the tests reported in this bulletin were made, was built under the direction of the University of Illinois and placed in operation in 1906. The equipment, which is for 500-volt direct current operation, was placed so as to provide facilities for the instruction of students as well as for conducting investigations concerning various features of electric car operation. For this purpose the switch group, circuit breaker, limit switch and certain other parts of the equipment were placed within the car where their action under all conditions might readily be seen. The weight of the car with its equipment, subject to certain corrections, is 55 150 pounds. The corrections referred to are necessitated by additions to the equipment and changes made therein at different times. The general design of the car is shown in Figs. 5, 6 and 7.

Car Body.—The car body, which is of the double-end type commonly used in moderately heavy interurban service, was built by the Jewett Car Co., of Newark, Ohio. Its principal dimensions are given in Fig. 7. The cross-sectional area of the body and trucks is 90 square feet. The vestibules are of the round end type. Ball bearing center plates were installed between tests 29 and 30.

Trucks.—The car body is mounted upon Standard Motor Truck Company C-60 type trucks whose main dimensions are:—

Distance from center to center of trucks 23 ft. 3 in.

Wheel base, 6 ft. 4 in.

Lateral play of axle journals, 3/16 in.

Axle journals, 4¼ in. × 8 in.

Diameter of wheels, 33 in.

Weight of truck exclusive of electrical equipment, 7824 pounds.

On one truck there are four rolled steel wheels, while those on the other truck are chilled cast iron. Both sets have the standard M. C. B. tread and flange.

Motors.—On each truck are two number 101-D Westinghouse 500-volt, direct current motors, each one having a commercial rating of 50 H. P. They are mounted on the axles and geared thereto in the ratio of 22:62. The characteristic curves are shown in Fig. 8.

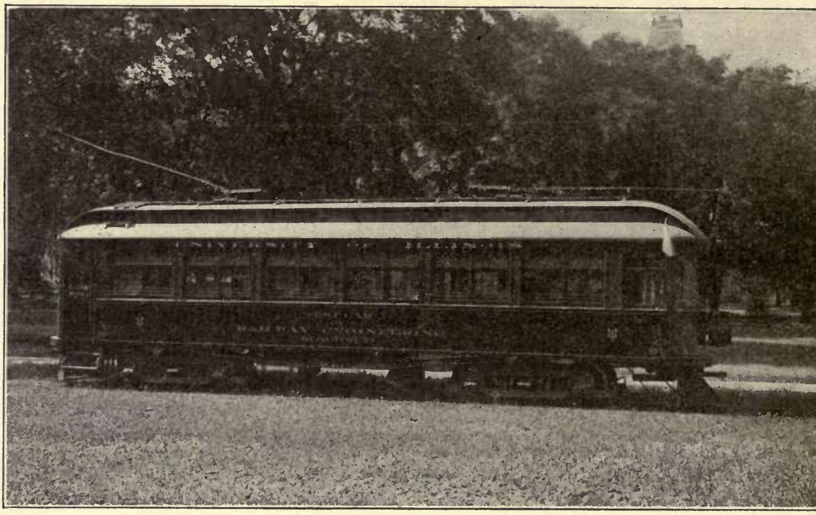

FIG. 5. THE ELECTRIC RAILWAY TEST CAR.

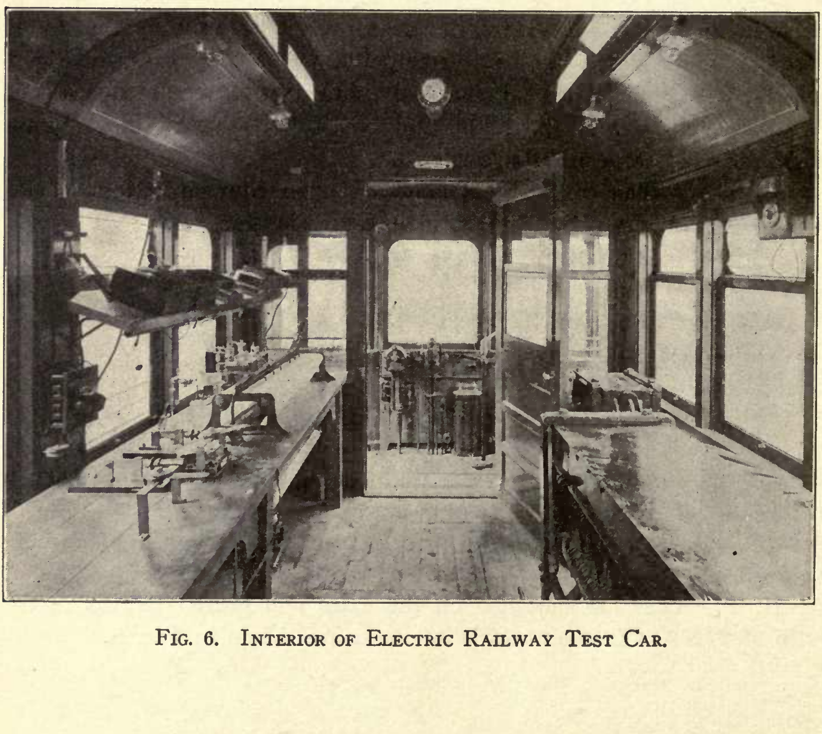

FIG. 6. INTERIOR OF ELECTRIC RAILWAY TEST CAR.

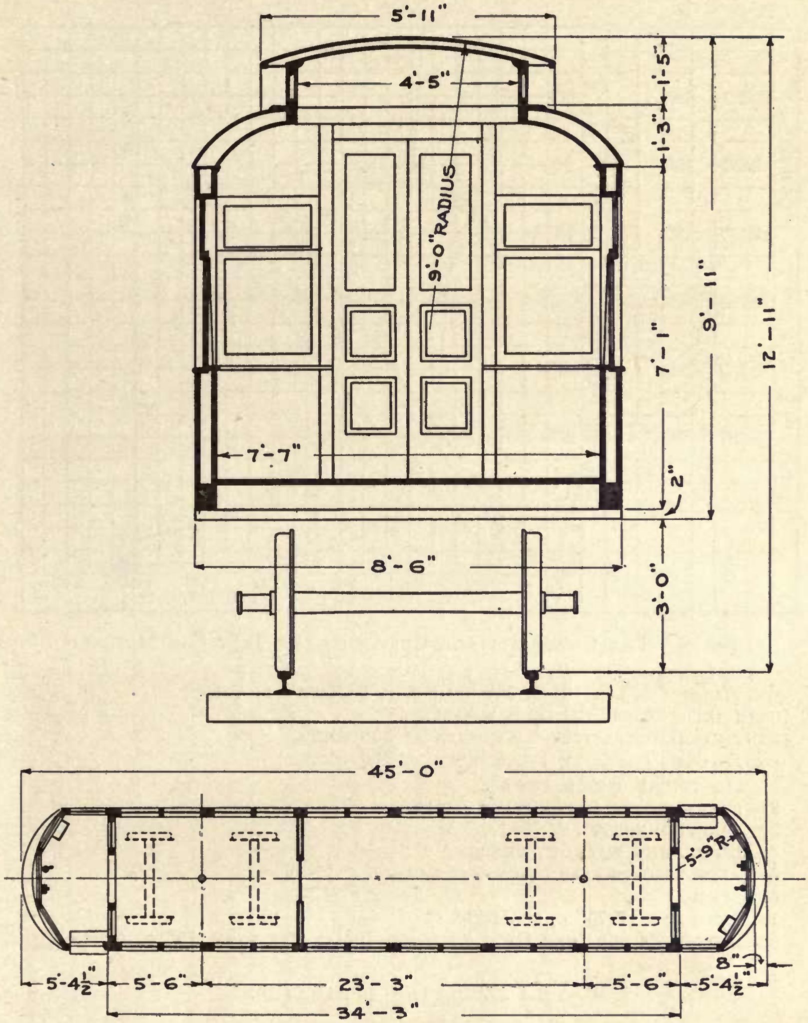

FIG. 7. PLAN AND CROSS SECTION OF THE ELECTRIC RAILWAY TEST CAR.

Control Equipment.—The motor control equipment is that known as the Westinghouse unit switch system of multiple control. In this type of control the switches which make the necessary connections and short circuit the starting resistances are operated by compressed air from the brake reservoir. The valves which control the air are operated from the master controller through the medium of magnets and a low voltage storage battery circuit. Acceleration is governed by a limit switch the armature of which is weighted to give the desired rate.

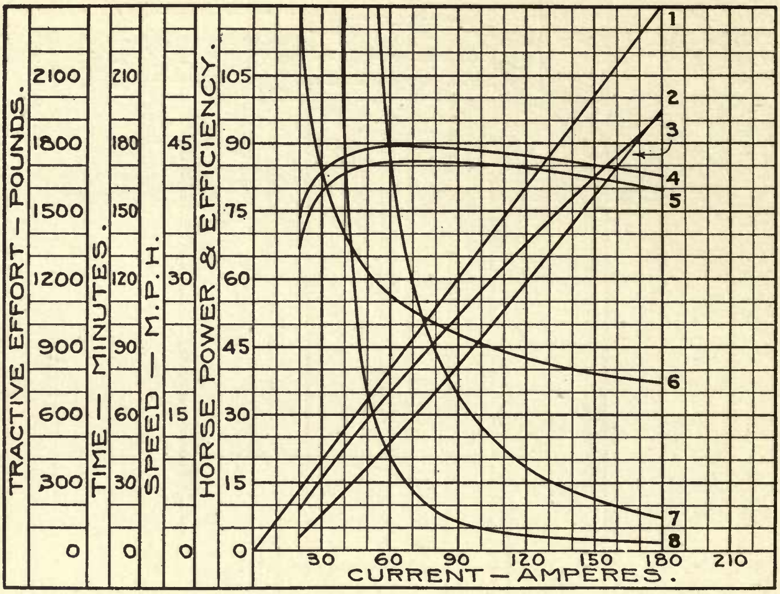

FIG. 8. THE CHARACTERISTIC CURVES OF THE TEST CAR MOTORS.

WESTINGHOUSE NO. 101-D, 500 VOLT D. C. RAILWAY MOTOR.
GEAR RATIO 22:62. 33 INCH WHEELS.
CONTINUOUS CAPACITY 46 AMPERES AT 300 VOLTS.
CONTINUOUS CAPACITY 42 AMPERES AT 400 VOLTS.

1. ELECTRICAL HORSE POWER.
2. BRAKE HORSE POWER WITH GEARS.
3. TRACTIVE EFFORT.
4. EFFICIENCY WITHOUT GEARS.
5. APPROXIMATE EFFICIENCY WITH GEARS.
6. SPEED.
7. TIME TO RISE 75° C. FROM 25° C.
8. SAFE TIME FOR LOAD IN SERVICE FOR 20° C. RISE FROM 75° C.

THE RECORDING APPARATUS.

Within the car there is apparatus by means of which a continuous graphical record may be kept of motor current, voltage, speed, time, distance, location, and brake cylinder pressure upon a chart 40 inches in width.

The Chart.—Fig. 9 has been reproduced from a tracing of a portion of the chart for test No. 121. The records there shown are grouped more closely together than in the original record, and the transverse lines which mark one of the sections selected for calculation and some of the explanatory lettering do not appear thereon. This chart is

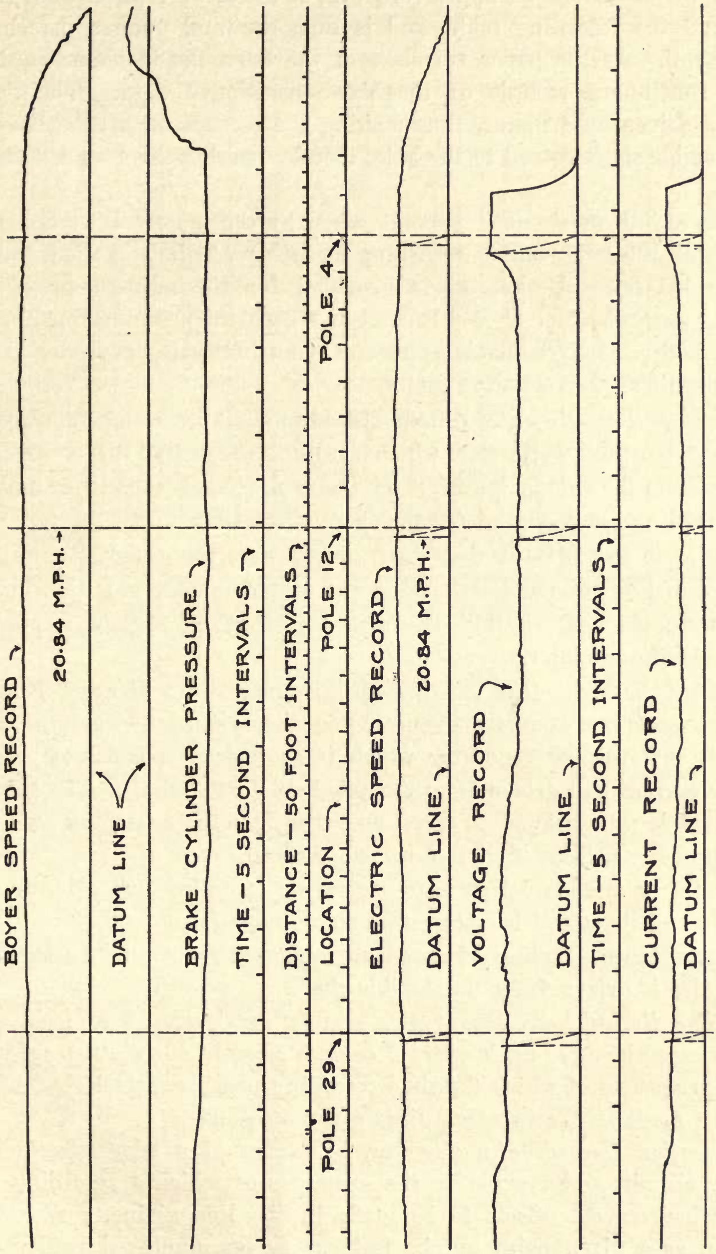

Fig. 9. A Portion of the Chart from Test 121.

caused to pass from a supply roll, over a series of tension and guide rolls and the recording table, and is then rewound upon a detachable record roll. As the paper travels over the table the instruments draw on it continuous records of the above mentioned data. The paper may be driven by a motor, thus making the records on a time base, or by a flexible shaft geared to the axle, thereby making them on a distance base.

Current Record.—The current taken by the motors is recorded by a General Electric graphic recording ammeter which is excited from a storage battery. A rheostat is provided for the adjustment of the exciting current which should be kept at a constant predetermined value. Check readings may be made by means of an indicating ammeter in the same circuit as the recording meter.

Voltage Record.—The voltage record is made by a General Electric graphic recording voltmeter which is likewise excited by a constant current from the storage battery. The same provision is made for making check readings as described for the current record.

Prior to test 121-122 these instruments were connected so as to give a record of line voltage, but for that and all subsequent tests the connections were changed so that the record is that of voltage across the terminals of one motor.

Speed Record.—One speed record is made by a General Electric graphic recording ammeter connected in the armature circuit of a ½ kilowatt low voltage generator which is excited by a constant storage battery current and driven from the axle by a flexible shaft. The current generated is proportional to speed and therefore the recording ammeter when properly calibrated gives a record of speed.

A Boyer mechanical speed recorder was installed just prior to test 103-104 and its record has been used on all subsequent tests.

Instantaneous values of speed are obtained from an "Autometer," which also is driven from the flexible shaft.

Time Record.—By means of a contacting device on a clock, electrical connections are made every 5 seconds so as to operate two magnets to the armatures of which the time recording pens are attached. Offsets are thus made in the two time lines every 5 seconds.

Location Record.—An observer, by means of a telegrapher's key, battery circuit, and magnet to the armature of which a recording pen is attached, causes offsets to be made in the line giving a record of location as a given point on the test car passes numbered trolley line

poles, stations, or other markers. This record enables one to correlate any position of the car with the profile.

Distance Record.—A pen operated electrically from a contacting device on one of the car wheels makes an offset in a line for every 50 feet of track passed over by the car. This record is used merely as a check on the distances obtained from a table giving the exact distance between any two trolley line poles.

Brake Cylinder Pressure.—A pressure gage connected to the brake cylinder has been modified so as to make a record upon the chart. This record is used merely to determine and to avoid those portions of tests during which the brakes were applied.

Auxiliary Apparatus.—The power consumed by the motors may be obtained from an integrating wattmeter. A separate wattmeter indicates the power consumed by the pump motors. For a part of the tests herein reported two water rheostats were placed in the trolley circuit for the purpose of cutting down the voltage and thereby obtaining lower speeds than it was otherwise possible to maintain.

APPENDIX II.

Methods Employed in Calculating the Results.

The steps in the process by which the final results have been reached are here explained in some detail. The description of the general process which has been given in Section IV of the body of the report is to be considered as supplementary to this Appendix. The data taken and the methods by which they were obtained have been described there and in Appendix I. Fig. 9 has been reproduced from a portion of the chart made by the recording apparatus during test number 121.

Selection of the Sections.—From the chart produced during each test, sections have been chosen for calculation by comparison of the profile and chart. As has been stated, only those sections were considered where the car was running on straight track, and over which no brake applications were made. They were selected so that the average speeds over the sections chosen from any particular test should cover as wide a range as possible, and so that the number of sections from east bound runs would be balanced by the same or approximately the same number from west bound runs. In this way the number of resistance determinations made from data obtained during runs against the wind were balanced by an approximately equal number for the opposite condition. In addition, the following were considered sufficient reasons for the rejection of any section of chart:

a. Any considerable variation of the current or voltage from the average value.

b. Heavy grades between the section limits. Level track or light uniform grades are of course the preferable conditions.

c. A large difference in the speed of the car when entering and when leaving the track section or at any points between the section limits.

Aside from other considerations it is highly desirable to choose both track and chart sections so that the energy consumed by acceleration and grade shall be as small as possible, in order that errors in their calculation shall have slight effect on the accuracy of the values of average net car resistance. When the variation in speed is large the energy required to produce acceleration is alone frequently greater than that required to overcome all other resistances combined.

Fig. 9 shows one of the chart sections selected from a run made over a track section lying between trolley line poles numbered 4 and 12. These limiting points are designated on Fig. 9 by numbered offsets in the location record. Parallel lines drawn through them and perpendicular to the location record line intercept all but four of the records at the points occupied by the pens at the moment when the car entered and left the track section. The four records in question, namely, current, voltage, brake cylinder pressure, and speed by the electrical recorder, are made by pens which move along arcs of circles and which are adjusted so that in their zero position their recording points lie in the same straight line as the other pens. For any but the zero reading, however, these pens take positions ahead of the others and consequently allowance must be made for this fact in determining their positions at the moments when the car passed the points of entrance and exit. This matter has been cared for by means of templates, as shown in Fig. 9.

The Calculations.—The result desired from each such section of chart is a value of average net car resistance. The following explanation of the derivation of each column of data in the tables should make clear all the processes involved in the production of the final results.

Table 1 gives a summary of test conditions. Tables 3 to 12 inclusive present original data, and intermediate and final results as follows:

Column 1. (Item No.) is self explanatory.

Column 2. (Test No.) is self explanatory.

Column 3. (Wind opposing or helping) is from original data.

Column 4. (Section limits) defines the track section as well as the chart section by stating the limiting points which have been designated by trolley line pole numbers. The location of each line pole or other marker is shown accurately upon the profiles.

Column 5. (Grade) is derived from column 4 and the profiles, and expresses the grade as the difference in elevation in feet between the entrance and exit points. A positive sign indicates that the car is going up grade.

Column 6. (Length of section) is derived from column 4 and a table giving the exact distance between any two trolley line poles.

Column 7. (Time) is derived from the time record on the chart by determining the number of whole and decimal parts of 5-second intervals included between the parallel lines drawn through the limiting points of the section.

Column 8. (Motor data) is from the original data.

Column 9. (Efficiency) is derived from columns 8, 13 and 14, and a table of efficiencies.

Tables 3 to 12 inclusive, in Appendix III, show that the voltage (column 13) varied from about 100 to 600 volts. The low voltages were due largely to the method of using rheostats on the car for the purpose of obtaining low speeds. It was thought that the efficiency curve for the motors at 500 volts was not accurate enough under such conditions and therefore one of the motors was removed from the truck and a series of efficiency tests made upon it at five different voltages, namely, 120, 200, 300, 400, and 500. From the results of these tests a set of efficiency curves for the test car motors with gears was constructed, the Westinghouse Electric & Machine Company's standard gear losses being used. The 500-volt curve, thus determined, corresponds with the curve provided by the manufacturer. From these curves the above mentioned table was compiled.

Column 10. (Item No.) is self explanatory.

Column 11. (Speed at entrance to the section) The height of the speed curve above its base line at the point occupied by the recording pen at the moment the car entered the track section represents the speed of the car at that moment, to some scale determined by a calibration curve. Such a curve was made for each test by plotting average speeds calculated from columns 6 and 7 against the corresponding average heights of the speed curve in sufficient number to determine a curve. Straight lines were found to satisfy the conditions and for each one the equation was found and used in the calculations.

Column 12. (Speed at exit from the section) is determined from the height of the speed curve at the point of exit, and the equation of the calibration curve as explained above.

Column 13. (Average voltage) is determined by first obtaining the average height of the voltage curve between the section limits. From a calibration table the voltage corresponding to the average height may be found and it is recorded in column 13.

Column 14. (Average current) is determined from the current curve in the same manner as column 13 from the voltage curve.

Column 15. (Energy imparted to the car by the current) is calculated by means of the equation—

$$E_c = W \times e \times T \times 2655.$$

in which E_c = the energy in foot pounds imparted to the car by the current.

W = Average watts, calculated from columns 13 and 14.

e = The efficiency of the motors and gears for the given current and voltage (Column 9).

T = The time in hours for the car to traverse the section = $\frac{\text{column 7}}{3600}$

2655 = foot pounds in one watt hour.

Column 16. (Energy imparted to the car by the change in kinetic energy between the entrance and exit points) is determined from the entrance and exit speeds (columns 11 and 12), and an equation expressing the relation between kinetic energy and the speed of the car. This equation was derived from a series of determinations of the force required to produce acceleration in the rotation of the revolving parts as well as of the force required to produce the acceleration in the motion of translation of the car as a whole. The equation follows:

$$E_k = (1995 + 5P)(S_1^2 - S_2^2)$$

in which E_k = The energy in foot pounds imparted to the car by the change in kinetic energy between the entrance and exit points.

S_1 = The speed of the car in miles per hour at the moment of entering the track section (column 11).

S_2 = The speed of the car in miles per hour at the moment of leaving the track section (column 12).

P = The number of additional 150 pounds above the weight of the car and its regular equipment, that is above 55 150 pounds. This item includes live load and special equipment.

1995 and 5 are constants derived from the inertia calculations referred to above.

A negative sign before the figures in column 16 indicates that the speed of the car had increased in passing over the track section and consequently that the kinetic energy possessed by the car at the moment it left the section was greater than when it entered it by the amount given. This energy had to be supplied by the current, by the grade, or by both current and grade.

Column 17. (Energy imparted to the car by the grade) is the product of the weight of the car (column 2, Table 1) and the difference in elevation in feet between the points of entrance and exit. A negative sign indicates that the car is going up grade and is consequently requiring additional energy for that purpose.

Column 18. (Net car resistance in pounds per ton)—The net

energy used in overcoming car resistance alone while traversing the track section is first found from columns 15, 16 and 17 by correcting the energy delivered by the current, for changes in speed and grade. From the net energy the average value for the section is found by dividing by the length of that section in feet (column 6), and this in turn is reduced to net car resistance in pounds per ton of car weight by dividing by the weight of the car in tons. This is the result desired from each chart section.

Column 19. (Average speed) is calculated from the length of the track section (column 6) and the time required to traverse that distance (column 7). Columns 18 and 19 provide the co-ordinates of the points plotted in Figs. 10 to 19.

Method of Obtaining the Mean Curves of Car Resistance for Tests of Groups A and B.—As described on page 13, the ordinates of points on the mean curves for the individual tests of groups A and B have been calculated by means of an equation which is based on the assumption that wind resistance varies as the square of the speed. The derivation of the equation follows:

Let R_s = the resistance at speed s excluding air resistance

R = the total resistance at speed $s = R_s + cs^2$ (1)

in which c = some constant quantity

R_a = the resistance for a run against the wind at speed s

$= R_s + c\,(s + v)^2$ (2)

in which v = the component of the wind velocity parallel to the track.

R_w = the resistance for a run at speed s with the wind

$= R_s + c\,(s - v)^2$ (3)

Subtracting equation (3) from (2) and solving for c

$$c = \frac{R_a - R_w}{4\,sv} \tag{4}$$

Substituting (4) in equation (2) and solving for R_s

$$R_s = R_a - \frac{R_a - R_w}{4\,sv}\,(s + v)^2 \tag{5}$$

Substituting equation (5) in equation (1)

$$R = R_a - \frac{R_a - R_w}{4\,s}\,(2s + v) \tag{6}$$

Equation (6) is the one sought. The mean curves of groups A and B, calculated by means of this equation, and those of group C, determined as described on page 16, after being modified as described on page 14 to conform to the general shape, were accepted as the results desired from the individual tests.

APPENDIX III.

The Results of the Individual Tests.

Note.—In the figures solid dots are for runs with the wind, and open circles are for runs against the wind.

Table 3

Test No. 15-16.

1	2	3	4	5	6	7	8	9
							Motor Data	
Item No.	Test No.	Wind Opposing or Helping	Section Limits. Trolley Line Pole Numbers.	Grade. Rise or Fall Over Section. + Up — Down	Length of Track Section	Time to Run Over Section	Number in Use and Connection *	Efficiency of Motors and Gears
		O or H		Feet	Feet	Sec's.		%
1	15	H	1 620–1 575	+13.20	4 009	77.21	4 M	85.1
2	"	"	1 470–1 440	+ 4.17	2 991	72.14	"	78.4
3	"	"	1 440–1 380	— 5.34	5 994	127.94	"	79.6
4	"	"	1 380–1 345	—10.15	3 503	63.14	"	77.5
5	"	"	1 335–1 305	— 3.45	2 986	53.30	"	81.0
6	"	"	1 295–1 270	+ 4.05	2 495	42.50	"	81.4
7	"	"	1 250–1 230	— 3.74	1 987	32.20	"	82.4
8	"	"	1 070– 970	— 9.92	9 987	173.99	"	81.2
9	16	O	970–1 000	+ 4.23	2 958	61.88	"	82.0
10	"	"	1 000–1 035	+ 3.53	3 480	69.21	"	82.2
11	"	"	1 035–1 070	+ 2.15	3 549	66.02	"	82.9
12	"	"	1 115–1 135	— 1.19	1 988	38.47	"	85.4
13	"	"	1 270–1 295	— 4.05	2 495	42.82	"	82.4
14	"	"	1 305–1 330	+ 3.41	2 488	43.66	"	81.8
15	"	"	1 400–1 430	+ 1.57	2 998	67.76	"	80.7
16	"	"	1 455–1 480	+ 0.42	2 492	52.40	"	81.0
17	"	"	1 480–1 535	+17.12	5 473	110.77	"	81.4
18	"	"	1 580–1 620	—14.74	3 576	67.54	"	81.4

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

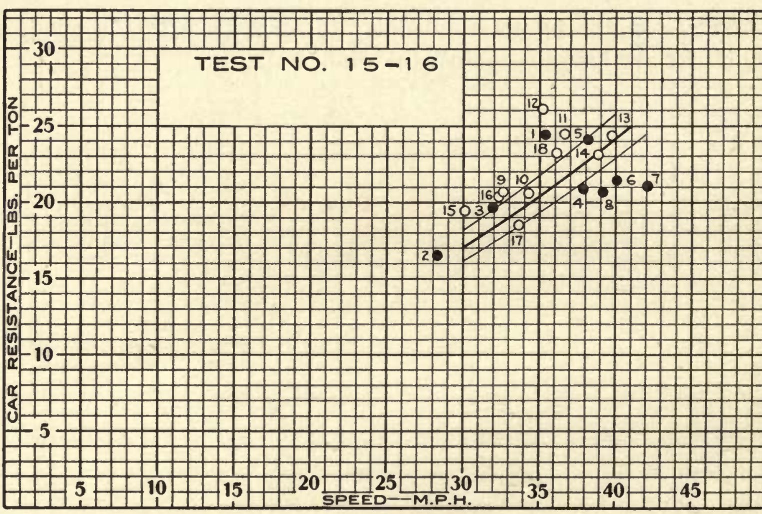

Fig. 10.

TABLE 3 (Continued)

TEST NO. 15-16.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to Car				
Item No.	At Entrance to Section	At Exit From Section	Average Voltage	Average Current	By the Current	By the Change in Kinetic Energy	By the Grade	Net Car Resistance	Average Speed Over the Section
	M. P. H.	M. P. H.	Volts	Amp's.	Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Lbs. Per Ton	M. P. H.
1	33.46	38.32	510	171.7	4 243 500	— 720 400	—747 100	24.46	35.42
2	26.65	29.24	351	132.1	1 934 200	— 298 900	—236 000	16.51	28.27
3	29.24	35.08	394	128.4	3 800 000	— 775 700	+302 200	19.60	31.95
4	35.08	36.37	411	113.4	1 682 000	— 190 300	+574 500	20.84	37.83
5	37.99	38.64	469	129.9	1 940 000	— 102 860	+195 300	24.05	38.20
6	39.94	39.29	494	129.9	1 637 000	+ 106 350	—229 200	21.44	40.04
7	37.99	40.58	534	133.3	1 392 800	— 420 200	+211 700	21.06	42.07
8	34.10	41.23	467	131.5	6 398 500	—1 109 100	+561 500	20.69	39.15
9	29.57	32.16	436	141.1	2 302 000	— 330 150	—239 400	20.69	32.59
10	32.16	35.40	452	141.1	2 676 000	— 452 000	—199 800	20.55	34.28
11	35.40	37.02	492	142.0	2 820 000	— 242 300	—121 700	24.45	36.64
12	29.89	36.37	554	170.1	2 283 000	— 886 600	+ 67 350	26.01	35.24
13	36.70	38.96	523	135.1	1 839 000	— 353 100	+229 200	24.28	39.73
14	37.99	37.34	492	132.6	1 718 000	+ 101 100	—193 000	23.09	38.85
15	27.62	31.19	388	138.8	2 172 000	— 433 550	— 88 860	19.44	30.18
16	28.60	31.19	422	134.6	1 778 000	— 319 800	— 23 770	20.34	32.43
17	31.19	32.16	436	136.6	3 961 000	— 126 900	—969 000	18.49	33.68
18	29.24	36.37	456	134.4	2 485 100	— 966 000	+834 300	23.25	36.10

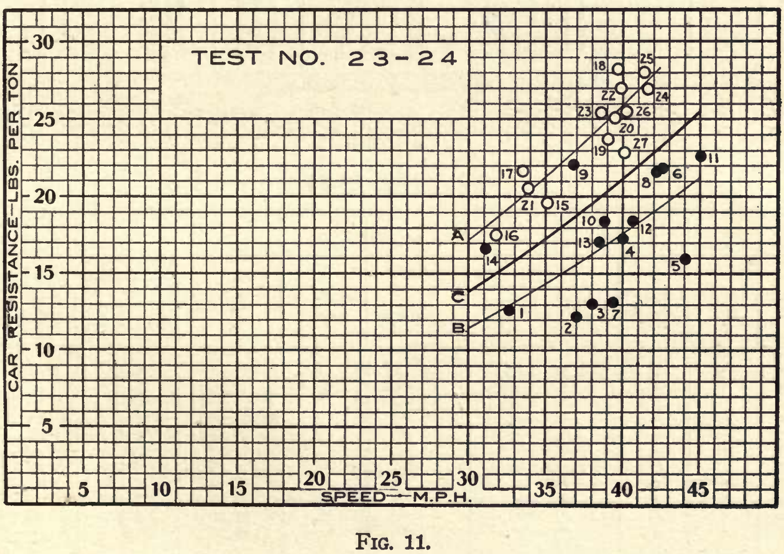

FIG. 11.

Table 4

Test No. 23-24.

1	2	3	4	5	6	7	8	9
				Grade			Motor Data	
Item No.	Test No.	Wind Opposing or Helping	Section Limits. — Trolley Line Pole Numbers.	Rise or Fall Over Section — + Up — Down	Length of Track Section	Time to Run Over Section	Number in Use and Connection *	Efficiency of Motors and Gears
		O or H		Feet	Feet	Sec's		%
1	23	H	1 471 -1 462	+0.2	897	18.71	4 M	83.5
2	"	"	1 462 -1 453	+0.6	896	16.50	" "	82.6
3	"	"	1 402.7-1 396.7	—1.94	600	10.75	" "	76.6
4	"	"	1 394.2-1 388.2	—0.16	594	10.12	" "	80.8
5	"	"	1 361 -1 343	—1.49	1 804	27.91	" "	79.3
6	"	"	1 291 -1 282	—0.06	901	14.42	" "	80.0
7	"	"	1 081 -1 075	+0.78	582	10.07	" "	84.5
8	"	"	1 012 - 970	—4.76	4 144	66.90	" "	81.8
9	"	"	917.2- 901.75	+1.02	1 529	28.33	" "	83.3
10	"	"	871.5- 853.4	+2.15	1 803	31.65	" "	79.9
11	"	"	780.4- 720.5	—6.74	5 970	90.30	" "	83.4
12	"	"	567.4- 540.5	+0.43	2 689	45.07	" "	82.9
13	"	"	489.3- 468.5	+0.50	2 083	36.89	" "	81.2
14	"	"	190.5- 150.5	—3.96	3 948	86.45	" "	80.0
15	24	O	168.8- 190.5	+3.19	2 090	40.56	" "	83.2
16	"	"	403.1- 420.2	+1.33	1 664	35.60	" "	83.1
17	"	"	459.5- 492.3	+0.53	3 276	66.55	" "	80.5
18	"	"	550.5- 570.3	—0.62	1 977	33.94	" "	82.5
19	"	"	625.3- 687.5	+2.29	6 270	109.49	" "	84.3
20	"	"	726.3- 780.4	+5.57	5 392	92.98	" "	84.0
21	"	"	1 039 -1 075	+2.53	3 678	74.00	" "	83.3
22	"	"	1 111 -1 141	—0.98	2 982	50.94	" "	84.5
23	"	"	1 226.5-1 251.5	+5.48	2 483	43.86	" "	83.9
24	"	"	1 273 -1 297.5	—2.46	2 443	40.00	" "	83.8
25	"	"	1 306.8-1 334	+2.99	2 707	44.56	" "	83.7
26	"	"	1 343 -1 373	+4.97	3 004	50.88	" "	82.2
27	"	"	1 406 -1 465	—5.11	5 889	100.11	" "	82.0

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

Table 5

Test No. 73-74.

1	2	3	4	5	6	7	8	9
							Motor Data	
Item No.	Test No.	Wind O or H	Section Limits	Grade	Length of Section	Time	No. and Connection *	Efficiency
1	73	H	1 470-1 455	+0.56	1 495	23.78	4 M	81.1
2	"	"	" "	"	"	24.60	4 M	81.9
3	"	"	" "	"	"	29.00	4 M	80.4
4	"	"	" "	"	"	28.58	4 S	84.7
5	"	"	" "	"	"	28.31	4 S	84.7
6	"	"	" "	"	"	37.80	C	—
7	74	O	1 455-1 470	—0.56	"	26.91	4 M	82.7
8	"	"	" "	"	"	28.40	4 M	83.3
9	"	"	" "	"	"	30.35	4 S	85.5
10	"	"	" "	"	"	31.94	4 S	85.8
11	"	"	" "	"	"	38.58	C	—

*S=Series-multiple. M=Multiple. Sw=Switchicg. C=Coasting.

Table 4 (Continued)

Test No. 23-24.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to Car				
Item No.	At Entrance to Section	At Exit from Section	Average Voltage	Average Current	By the Current	By the Change in Kinetic Energy	By the Grade	Net Car Resistance	Average Speed Over Section
	M. P. H.	M. P. H.	Volts	Amp's.	Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Lbs. Per Ton	M. P. H
1	31.33	34.97	464	153.8	822 230	— 493 520	— 11 250	12.58	32.69
2	34.97	37.16	455	145.3	664 520	— 323 040	— 33 750	12.21	37.02
3	38.61	39.71	435	108.5	286 630	— 176 180	+109 120	13.01	38.05
4	39.52	40.07	482	127.0	369 150	— 89 520	+ 9 000	17.28	40.02
5	43.53	44.62	477	118.5	922 650	— 196 490	+ 83 810	15.96	44.05
6	46.99	46.81	503	120.3	514 820	+ 34 530	+ 3 380	21.81	42.60
7	39.34	40.98	528	159.4	528 160	— 269 380	— 43 870	13.13	39.40
8	41.71	44.62	529	129.5	2 764 800	— 513 750	+267 750	21.61	42.23
9	37.34	39.16	515	144.0	1 290 700	— 284 730	— 57 380	22.06	36.80
10	39.16	39.16	459	123.0	1 052 900	0	—120 900	18.38	38.84
11	42.26	47.90	605	132.6	4 455 700	—1 039 900	+379 120	22.60	45.08
12	37.16	40.98	536	137.5	2 030 800	— 610 420	— 24 190	18.46	40.68
13	35.15	37.34	465	131.5	1 350 900	— 324 650	— 28 130	17.07	38.50
14	29.14	37.34	422	127.2	2 737 900	—1 114 800	+222 700	16.62	31.14
15	34.24	36.97	464	149.6	1 727 500	— 397 550	—179 400	19.57	35.13
16	29.14	33.70	448	151.4	1 479 800	— 586 000	— 74 810	17.50	31.85
17	32.42	33.70	426	130.8	2 201 500	— 173 080	— 29 810	21.69	33.57
18	38.61	38.25	526	136.0	1 477 200	+ 56 580	+ 34 880	28.21	39.71
19	33.15	41.89	548	151.6	5 655 200	—1 341 200	—128 800	23.73	39.04
20	37.34	40.62	548	146.9	4 636 900	— 522 920	—313 310	25.06	39.50
21	30.05	37.16	476	150.0	3 245 900	— 977 230	—142 300	20.55	33.89
22	37.89	40.98	571	149.4	2 708 100	— 498 380	+ 55 130	27.00	39.89
23	39.16	39.52	536	147.1	2 139 800	— 57 920	—308 300	25.40	38.61
24	41.53	42.99	560	142.0	1 965 800	— 252 350	+138 400	26.95	41.64
25	42.80	41.89	548	142.4	2 146 500	+ 157 600	—168 200	28.05	41.41
26	42.26	40.44	517	133.3	2 125 700	+ 307 800	—279 560	25.49	40.26
27	38.25	42.07	515	132.2	4 121 800	— 627 450	+287 440	22.83	40.11

Table 5 (Continued)

Test No. 73-74.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to Car				
Item No.	Entrance	Exit	Average Voltage	Average Current	By Current	By Kinetic Energy	By Grade	Net Car Resistance	Average Speed
1	41.35	42.21	516	125.8	923 200	—146 950	—31 720	17.58	42.87
2	40.83	41.52	520	130.5	1 008 000	—116 200	"	20.31	41.45
3	33.56	35.29	443	127.7	972 800	—243 600	"	16.47	35.13
4	36.16	36.85	528	80.9	762 700	—103 000	"	14.83	35.72
5	35.12	35.99	530	81.2	761 100	—126 500	"	14.23	36.00
6	30.10	24.09	—	—	—	+666 000	"	14.98	26.96
7	36.68	37.20	507	138.6	1 153 000	— 78 560	+31 720	26.12	37.87
8	34.60	36.33	506	144.9	1 279 000	—250 950	"	25.02	35.89
9	32.52	33.39	530	92.1	934 100	—117 250	"	20.02	33.58
10	30.97	32.87	528	98.0	1 046 000	—248 050	"	19.59	31.91
11	30.10	24.05	—	—	—	+669 950	"	16.56	26.42

TABLE 6

TEST No. 77-78.

1	2	3	4	5	6	7	8	9
				Grade			Motor Data	
Item No.	Test No.	Wind Opposing or Helping	Section Limits. — Trolley Line Pole Numbers	Rise or Fall Over Section — + Up — Down	Length of Track Section	Time to Run Over Section	Number in Use and Connection *	Efficiency of Motors and Gears
		O or H		Feet	Feet	Sec's.		%
1	77	H	1 470–1 455	+0.56	1 495	23.03	4 M	78.5
2	78	O	1 455–1 470	—0.56	"	27.68	4 M	82.3
3	77	H	1 470–1 455	+0.56	"	32.87	2 M	85.0
4	78	O	1 455–1 470	—0.56	"	32.57	2 M	85.7
5	77	H	1 470–1 455	+0.56	"	35.48	2 M	81.6
6	78	O	1 455–1 470	—0.56	"	36.26	2 M	78.9
7	77	H	1 470–1 455	+0.56	"	38.01	2 M	79.3
8	77	H	1 470–1 455	+0.56	"	57.22	C	
9	78	O	1 455–1 470	—0.56	"	95.00	C	
10	77	H	1 470–1 455	+0.56	"	85.00	C	
11	78	O	1 455–1 470	—0.56	"	79.45	C	
12	77	H	1 470–1 455	+0.56	"	77.58	C	
13	78	O	1 455–1 470	—0.56	"	80.06	C	
14	78	O	1 455–1 470	—0.56	"	29.82	4 M	82.2

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

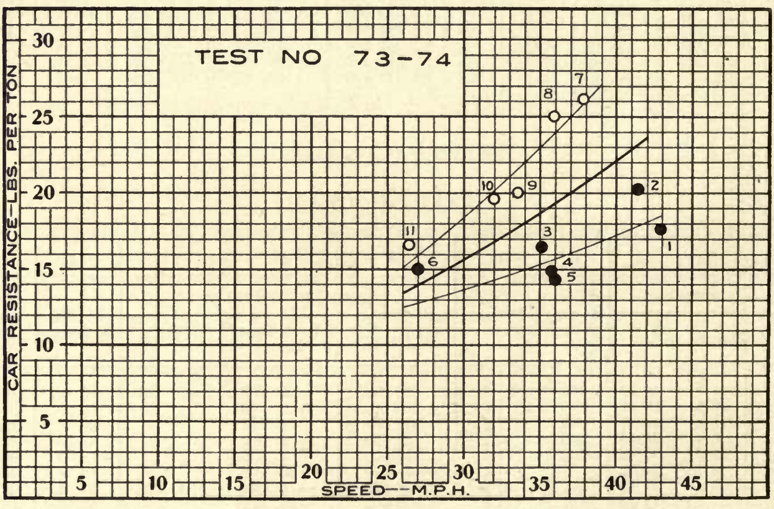

FIG. 12.

Table 6 (Continued)

Test No. 77-78.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to the Car				
Item No.	At Entrance to Section	At Exit from Section	Average Voltage	Average Current	By the Current	By the Change in Kinetic Energy	By the Grade	Net Car Resistance	Average Speed Over the Section
	M. P. H.	M. P. H.	Volts	Amp's.	Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Lbs. Per Ton	M. P. H.
1	45.22	44.46	507	112.4	759 750	+139 720	—31 810	20.44	44.25
2	35.48	37.01	499	136.8	1 146 960	—227 360	+31 810	22.41	36.82
3	29.94	31.85	480	89.5	885 210	—241 940	—31 810	14.40	31.01
4	34.34	36.05	507	98.7	1 029 860	—246 750	+31 810	19.19	31.29
5	28.61	29.94	510	64.9	706 830	—159 640	—31 810	12.14	28.72
6	27.84	26.31	499	57.6	606 320	+169 840	+31 810	19.03	28.11
7	26.12	25.17	420	61.1	570 050	+ 99 890	—31 810	15.03	26.82
8	19.06	12.37				+431 050	—31 810	9.40	17.81
9	14.85	6.64				+361 690	+31 810	9.27	10.73
10	15.43	10.46				+263 780	—31 810	5.46	11.99
11	17.15	8.55				+453 090	+31 810	11.42	12.83
12	15.04	9.89				+263 200	—31 810	5.45	13.14
13	17.72	8.93				+480 220	+31 810	12.06	12.73
14	31.66	34.72	412	146.0	1 086 840	—416 400	+31 810	16.54	34.18

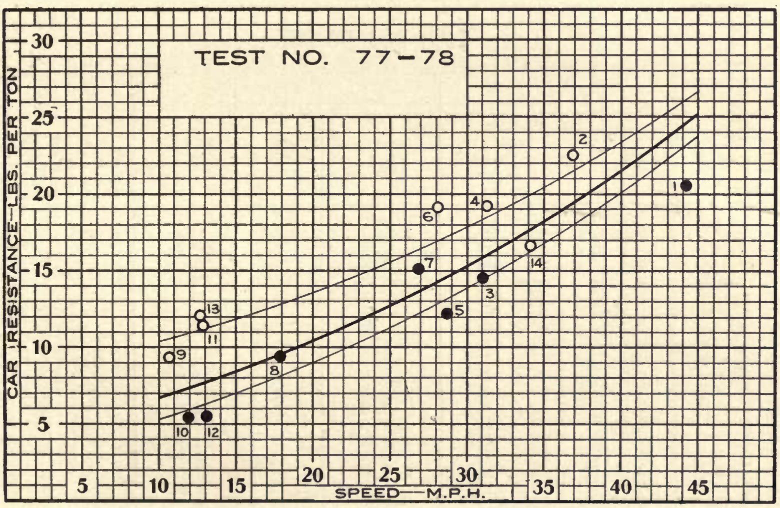

Fig. 13.

Table 7

Test No. 91-92.

1	2	3	4	5	6	7	8	9
							Motor Data	
Item No.	Test No.	Wind Opposing or Helping	Section Limits. Trolley Line Pole Numbers	Grade. Rise or Fall Over Section. + Up — Down	Length of Track Section	Time to Run Over Section	Number in Use and Connection *	Efficiency of Motors and Gears
		O or H		Feet	Feet	Sec's.		%
1	92	O	1 455-1 470	—0.56	1 495	31.50	4 M	81.5
2	91	H	1 470-1 455	+0.56	"	25.61	4 M	78.0
3	92	O	1 455-1 470	—0.56	"	29.80	4 M	82.0
4	91	H	1 470-1 455	+0.56	"	30.35	C	
5	92	O	1 455-1 470	—0.56	"	43.89	C	
6	91	H	1 470-1 455	+0.56	"	36.46	C	
7	92	O	1 455-1 470	—0.56	"	37.86	C	
8	91	H	1 470-1 455	+0.56	"	44.96	C	
9	92	O	1 455-1 470	—0.56	"	45.94	C	
10	91	H	1 470-1 455	+0.56	"	41.47	C	
11	92	O	1 455-1 470	—0.56	"	63.71	C	

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

Table 8

Test No. 95-96.

1	2	3	4	5	6	7	8	9
							Motor Data	
Item No.	Test No.	Wind O or H	Section Limits	Grade	Length of Section	Time	No. and Connection *	Efficiency
1	95	H	1 470-1 455	+0.56	1 495	21.97	4 M	79.6
2	96	O	1 455-1 470	—0.56	"	27.55	"	82.6
3	95	H	1 470-1 455	+0.56	"	23.90	"	81.2
4	96	O	1 455-1 470	—0.56	"	27.42	"	82.0
5	95	H	1 470-1 455	+0.56	"	24.70	"	81.2
6	96	O	1 455-1 470	—0.56	"	28.40	"	82.6
7	95	H	1 470-1 455	+0.56	"	43.37	4 S	72.9
8	96	O	1 455-1 470	—0.56	"	58.10	4 S	73.6
9	95	H	1 470-1 455	+0.56	"	32.00	4 M	83.0
10	96	O	1 455-1 470	—0.56	"	33.10	"	83.1
11	95	H	1 470-1 455	+0.56	"	27.50	"	80.5
12	96	O	1 455-1 470	—0.56	"	30.20	"	82.7
13	95	H	1 470-1 455	+0.56	"	38.05	C	
14	96	O	1 455-1 470	—0.56	"	33.30	C	
15	95	H	1 470-1 455	+0.56	"	37.25	C	
16	96	O	1 455-1 470	—0.56	"	35.20	C	
17	95	H	1 470-1 455	+0.56	"	48.05	C	
18	96	O	1 455-1 470	—0.56	"	39.75	C	

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

Table 7 (Continued)

Test No. 91-92.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to the Car				
Item No.	At Entrance to Section	At Exit from Section	Average Voltage	Average Current	By the Current	By the Change in Kinetic Energy	By the Grade	Net Car Resistance	Average Speed Over the Section
	M. P. H.	M. P. H.	Volts	Amp's.	Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Lbs. Per Ton	M. P. H.
1	32.71	33.24	454	134.7	1 157 860	— 71 130	—31 560	25.05	32.36
2	40.52	41.41	472	112.5	782 280	—148 390	+31 560	15.80	39.82
3	34.13	34.48	472	137.1	1 166 190	— 48 870	—31 560	25.78	34.21
4	35.01	32.00				+410 460	+31 560	10.50	33.59
5	27.56	20.10				+723 530	—31 560	16.43	23.22
6	28.80	25.78				+335 430	+31 560	8.71	27.96
7	30.93	22.76				+892 650	—31 560	20.44	26.92
8	22.76	18.85				+331 080	+31 560	8.61	22.67
9	27.38	17.43				+907 320	—31 560	20.79	22.19
10	26.67	22.23				+441 830	+31 560	11.24	24.58
11	20.63	12.10				+568 150	—31 560	12.74	16.00

Table 8 (Continued)

Test No. 95-96.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to Car				
Item No.	Entrance	Exit	Average Voltage	Average Current	By Current	By Kinetic Energy	By Grade	Net Car Resistance	Average Speed
1	46.44	46.13	518	117.5	785 010	+ 58 398	—31 556	19.27	46.40
2	37.87	37.24	499	138.7	1 161 600	+ 96 295	+31 556	30.61	37.00
3	41.21	43.11	516	126.6	934 980	—326 020	—31 556	13.71	42.65
4	37.24	37.24	482	135.4	1 082 200	0	+31 556	26.44	37.17
5	39.94	42.00	510	127.0	958 050	—343 500	—31 556	13.84	41.27
6	35.34	36.76	488	140.0	1 182 000	—208 350	+31 556	23.87	35.89
7	22.96	25.18	539	45.6	573 090	—217 480	—31 556	7.69	23.50
8	17.40	18.20	522	46.8	770 440	— 57 957	+31 556	17.66	17.54
9	27.72	33.75	450	150.4	1 325 700	—754 300	—31 556	12.82	31.85
10	29.62	33.27	452	151.2	1 386 400	—467 130	+31 556	22.57	30.80
11	35.97	37.56	477	125.4	976 580	—237 920	—31 556	16.79	37.07
12	32.16	33.75	477	142.7	1 253 800	—213 260	+31 556	25.45	33.75
13	30.26	26.45				+439 690	—31 556	9.69	26.79
14	34.54	26.61				+986 810	+31 556	24.18	30.61
15	29.31	25.02				+474 310	—31 556	10.51	27.36
16	32.32	25.34				+819 020	+31 556	20.19	28.96
17	22.96	18.83				+351 230	—31 556	7.59	21.21
18	28.35	20.89				+747 520	+31 556	18.50	25.64

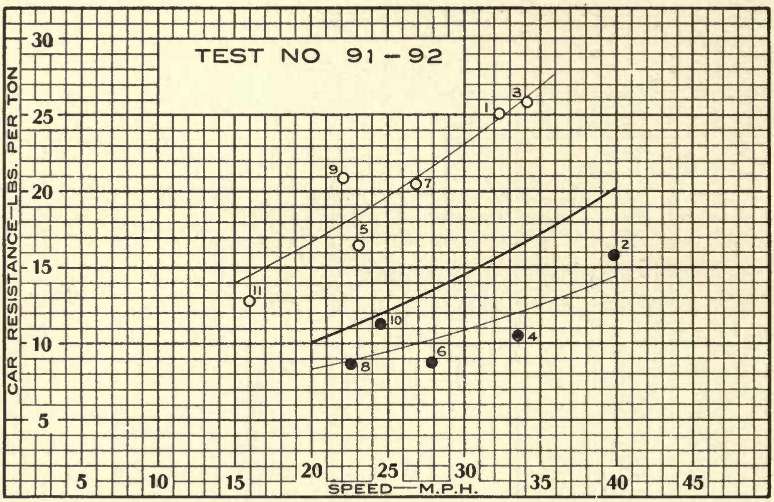
TEST NO 91 - 92
CAR RESISTANCE—LBS. PER TON
SPEED—M.P.H.
5
10
15
20
25
30
35
40
45

FIG. 14.

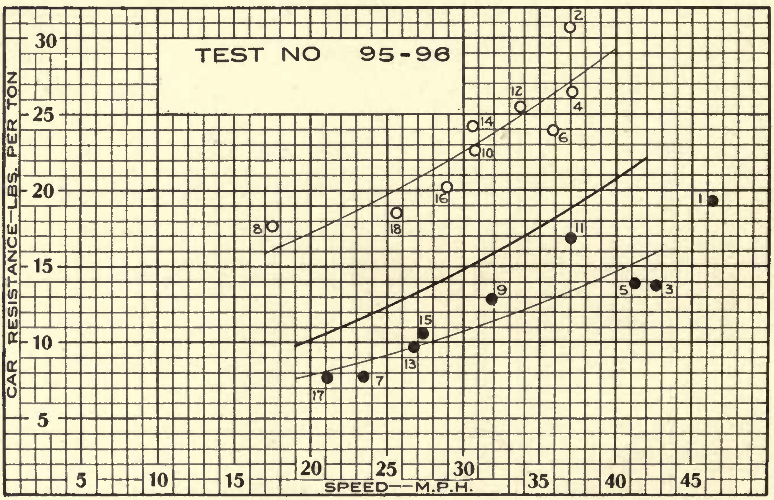
TEST NO 95-96
CAR RESISTANCE—LBS. PER TON
SPEED—M.P.H.
5
10
15
20
25
30
35
40
45

FIG. 15.

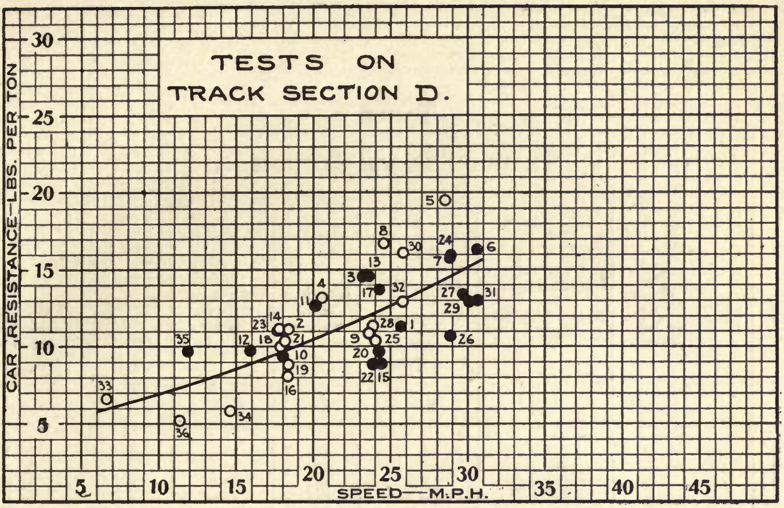
TESTS ON
TRACK SECTION D.
CAR RESISTANCE–LBS. PER TON
30
25
20
15
10
5
5
10
15
20
25
30
35
40
45
SPEED—M.P.H.

FIG. 16.

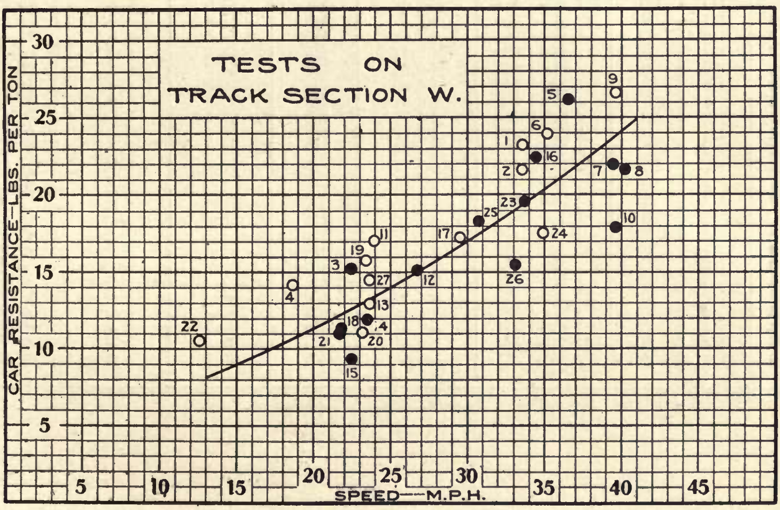
TESTS ON
TRACK SECTION W.
CAR RESISTANCE–LBS. PER TON
30
25
20
15
10
5
5
10
15
20
25
30
35
40
45
SPEED—M.P.H.

FIG. 17.

TABLE 9

TESTS ON TRACK SECTION D.

1	2	3	4	5	6	7	8	9
				Grade			Motor Data	
Item No.	Test No.	Wind Oppos-ing or Helping	Section Limits. — Trolley Line Pole Numbers	Rise or Fall Over Section — + Up — Down	Length of Track Section	Time to Run Over Section	Number in Use and Connection *	Efficiency of Motors and Gears
		O or H		Feet	Feet	Sec's.		%
1	109	H	1 571–1 566	+0.37	445	11.8	4 S	70.1
2	110	O	1 575–1 581	+2.54	522	19.3	4 S	81.4
3	109	H	1 571–1 563	+0.42	714	20.9	4 S	71.6
4	110	O	1 575–1 581	+2.54	522	17.3	4 S	82.5
5	110	O	1 575–1 581	+2.54	522	12.5	4 M	84.5
6	109	H	1 571–1 563	+0.42	714	15.9	4 M	79.9
7	109	H	1 571–1 563	+0.42	714	16.9	4 M	74.5
8	110	O	1 575–1 583	+4.60	700	19.4	4 M	80.9
9	110	O	1 575–1 583	+4.60	700	20.2	1	86.0
10	109	H	1 571–1 566	+0.37	445	16.8	C	——
11	111	H	1 581–1 575	—2.54	522	17.6	C	——
12	111	H	1 581–1 575	—2.54	522	22.3	C	——
13	111	H	1 571–1 563	+0.42	714	20.6	4 S	73.9
14	112	O	1 575–1 581	+2.54	522	20.0	4 S	79.4
15	111	H	1 571–1 566	+0.37	445	12.4	4 S	70.5
16	112	O	1 575–1 581	+2.54	522	19.4	4 S	76.6
17	111	H	1 571–1 566	+0.37	445	12.5	4 S	68.7
18	112	O	1 575–1 583	+4.60	700	26.7	4 S	80.8
19	112	O	1 575–1 583	+4.60	700	25.9	4 S	79.5
20	111	H	1 571–1 566	+0.37	445	12.5	4 S	61.5
21	112	O	1 575–1 583	+4.60	700	26.3	4 S	79.6
22	111	H	1 571–1 566	+0.37	445	12.7	4 S	66.0
23	112	O	1 575–1 583	+4.60	700	26.9	4 S	78.5
24	111	H	1 571–1 566	+0.37	445	10.5	4 M	72.6
25	112	O	1 575–1 581	+2.54	522	14.8	4 M	82.1
26	111	H	1 571–1 566	+0.37	445	10.5	4 M	67.8
27	111	H	1 571–1 566	+0.37	445	10.2	4 M	73.8
28	112	O	1 575–1 583	+4.60	700	20.0	4 M	74.5
29	111	H	1 571–1 566	+0.37	445	10.1	4 M	73.6
30	112	O	1 525–1 583	+4.60	700	18.5	4 M	80.8
31	111	H	1 571–1 566	+0.37	445	9.9	4 M	73.8
32	112	O	1 575–1 583	+4.60	700	18.5	4 M	81.5
33	114	O	1 575–1 578	+0.48	256	26.3	2 M	71.0
34	114	O	1 566–1 571	—0.37	445	20.7	2 M	65.0
35	113	H	1 571–1 566	+0.37	445	25.5	2 M	66.7
36	114	O	1 566–1 571	—0.37	445	26.7	2 M	70.5

*S=Series-multiplo. M=Multiple. Sw=Switching. C=Coasting.

TABLE 9 (Continued)

TESTS ON TRACK SECTION D.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to Car				
Item No.	At Entrance to the Section	At Exit from the Section	Average Voltage	Average Current	By the Current	By the Change in Kinetic Energy	By the Grade	Net Car Resistance	Average Speed Over the Section
	M. P. H.	M. P. H.	Volts	Amp's.	Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Lbs. Per Ton	M. P. H.
1	24.30	23.94	492	42.9	128 600	+ 35 700	— 21 070	11.30	25.72
2	16.74	17.64	496	65.0	373 400	— 63 580	—144 700	11.11	18.44
3	22.50	21.60	472	45.5	237 200	+ 81 560	— 23 920	14.50	23.23
4	19.80	20.34	565	64.8	385 300	— 44 530	—144 700	13.19	20.57
5	27.36	28.98	460	174.0	622 000	—187 600	—144 700	19.49	28.56
6	31.50	32.76	449	124.0	521 600	—166 400	— 23 920	16.29	30.60
7	27.90	27.90	344	107.5	343 200	0	— 23 920	15.71	28.80
8	23.94	24.30	368	148.0	630 300	— 35 700	—262 000	16.68	24.59
9	22.86	22.86	484	77.2	478 600	0	—262 000	10.86	23.61
10	19.80	18.00				+139 800	— 21 070	9.36	18.03
11	19.62	19.08				+ 42 510	+143 100	12.62	20.22
12	15.30	15.30				0	+143 100	9.72	15.95
13	23.04	22.50	496	47.8	266 100	+ 50 040	— 23 670	14.54	23.62
14	17.64	18.00	475	59.9	333 000	— 26 110	—143 100	11.13	17.78
15	24.12	24.12	467	43.9	132 100	0	— 20 850	8.88	24.46
16	18.00	18.00	443	54.0	262 000	0	—143 100	8.09	18.33
17	24.12	23.40	460	42.2	122 800	+ 69 620	— 20 850	13.68	24.26
18	17.64	18.00	477	63.6	482 400	— 26 110	—259 200	10.00	17.87
19	18.36	18.36	475	59.9	431 900	0	—259 200	8.76	18.42
20	23.22	22.68	417	38.8	91 680	+ 50 450	— 20 850	9.67	24.27
21	18.00	17.64	467	60.6	436 800	+ 26 110	—259 200	10.32	18.13
22	23.94	23.76	463	39.8	113 800	+ 17 460	— 20 850	8.81	23.88
23	18.36	17.46	454	58.1	410 500	+ 65 600	—259 200	11.00	17.74
24	28.44	28.26	337	105.5	200 000	+ 20 800	— 20 850	15.94	28.88
25	22.14	24.66	372	160.4	535 000	—240 000	—143 100	10.32	24.03
26	27.72	27.72	306	96.2	154 400	0	— 20 850	10.65	28.88
27	30.06	30.24	365	104.0	210 800	— 22 100	— 20 850	13.38	29.72
28	23.22	24.30	358	149.0	586 400	—104 400	—259 200	11.30	23.85
29	29.34	29.52	352	106.0	204 600	— 21 550	— 20 850	12.93	30.02
30	25.20	25.38	381	141.5	594 500	— 18 520	—259 200	16.06	25.79
31	30.78	30.96	365	105.0	206 500	— 22 600	— 20 850	13.00	30.63
32	24.66	25.74	387	145.0	624 000	—110 800	—259 200	12.88	25.80
33	5.76	6.66	113	62.3	97 020	— 22 700	— 26 980	6.58	6.64
34	13.32	13.68	160	45.1	71 640	— 19 730	+ 20 790	5.81	14.64
35	11.34	10.08	142	48.9	87 180	+ 54 810	— 20 790	9.69	11.89
36	8.64	10.44	149	55.4	114 300	— 69 710	+ 20 790	5.23	11.35

Table 10

Tests on Track Section W.

1	2	3	4	5	6	7	8	9
							Motor Data	
Item No.	Test No.	Wind O or H	Section Limits	Grade	Length of Section	Time	Number and Connection *	Efficiency
1	118	O	7-16	+1.37	1 189	24.1	4 M	78.4
2	118	O	21-30	—0.40	1 154	23.4	4 M	81.0
3	117	H	30-21	+0.40	1 154	35.1	4 S	63.1
4	118	O	7-16	+1.37	1 189	43.4	4 S	70.0
5	117	H	16- 7	—1.37	1 189	22.1	4 M	83.5
6	118	O	21-30	—0.40	1 154	22.3	4 M	80.1
7	117	H	16- 7	—1.37	1 189	20.5	4 M	78.2
8	117	H	16- 7	—1.37	1 189	20.1	4 M	79.2
9	118	O	21-30	—0.40	1 154	19.8	4 M	83.0
10	117	H	16- 7	—1.37	1 189	20.4	4 M	78.3
11	118	O	21-30	—0.40	1 154	32.7	4 S	73.7
12	117	H	30-21	+0.40	1 154	29.4	4 S	70.0
13	123	O	30-21	+0.40	1 154	33.2	4 S	70.6
14	124	H	21-30	—0.40	1 154	33.4	4 S	65.4
15	124	H	7-16	+1.37	1 189	35.9	4 S	66.8
16	124	H	21-30	—0.40	1 154	22.8	4 M	81.9
17	123	O	30-21	+0.40	1 154	36.6	4 M	82.9
18	124	H	21-30	—0.40	1 154	36.0	4 S	67.4
19	123	O	16- 7	—1.37	1 189	34.5	4 S	72.0
20	123	O	30-21	+0.40	1 154	33.8	4 S	74.7
21	124	H	21-30	—0.40	1 154	36.2	4 S	66.9
22	123	O	16- 7	—1.37	1 189	64.1	4 Sw	61.3
23	124	H	21-30	—0.40	1 154	32.3	4 M	77.9
24	123	O	30-21	+0.40	1 154	22.5	4 M	78.5
25	124	H	21-30	—0.40	1 154	25.5	4 M	74.3
26	124	H	21-30	—0.40	1 154	23.7	4 M	74.9
27	123	O	16- 7	—1.37	1 189	34.2	4 S	70.7

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

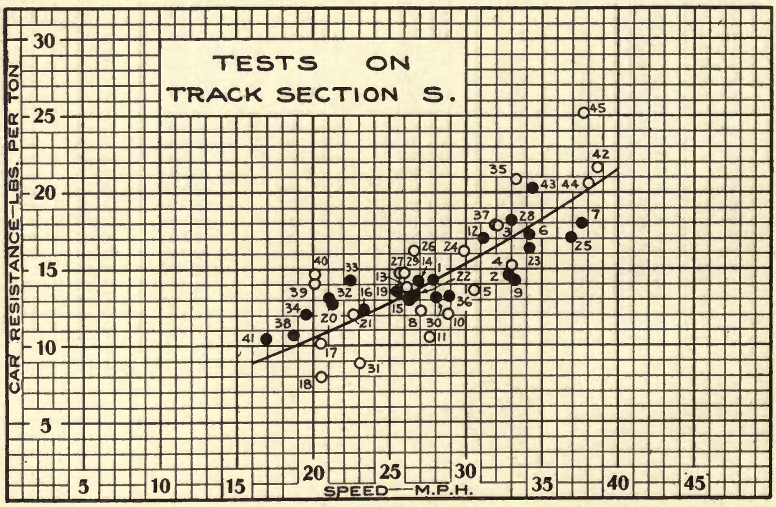

Fig. 18.

TABLE 10 (Continued)

TESTS ON TRACK SECTION W.

10	11	12	13	14	15	16	17	18	19
Item No.	Speed		Average Voltage	Average Current	Energy Imparted to the Car			Net Car Resistance	Average Speed
	Entrance	Exit			By Current	By Kinetic Energy	By Grade		
1	35.28	34.02	407	119.0	674 850	+177 260	—76 990	23.20	33.61
2	33.48	34.56	449	131.7	826 550	—149 170	+22 480	21.58	33.60
3	23.76	21.24	415	42.5	288 140	+230 200	—22 480	15.22	22.41
4	19.44	18.54	399	52.0	464 910	+ 69 390	—76 990	14.10	18.66
5	36.18	38.34	537	153.5	1 121 800	—326 750	+76 990	26.10	36.65
6	36.00	36.00	454	125.8	752 340	0	+22 480	23.89	35.27
7	40.68	40.50	467	113.5	626 610	+ 29 660	+76 990	21.95	39.51
8	42.12	42.30	492	116.8	674 720	— 30 850	+76 990	21.58	40.31
9	40.32	41.04	555	142.5	958 580	—118 920	+22 480	26.59	39.70
10	40.32	41.04	473	114.5	638 020	—118 920	+76 990	17.84	39.72
11	23.76	24.30	555	59.0	582 090	— 52 680	+22 480	17.01	24.05
12	27.18	26.64	592	50.3	451 990	+ 59 000	—22 480	15.06	26.75
13	23.40	23.58	256	52.3	462 930	— 17 340	—22 700	12.92	23.69
14	23.04	22.50	225	44.7	324 130	+ 42 510	+22 700	11.89	23.54
15	20.70	20.34	220	46.6	362 570	+ 30 290	—77 750	9.34	22.56
16	34.20	35.28	460	136.7	865 940	—153 830	+22 700	22.44	34.47
17	25.74	29.88	427	152.5	1 059 000	—472 050	—22 700	17.23	29.55
18	20.70	21.06	222	47.5	377 400	— 30 820	+22 700	11.28	21.83
19	22.50	23.40	268	54.8	538 040	— 84 690	+77 750	15.74	23.47
20	20.34	23.40	290	60.9	657 690	—274 380	—22 700	11.01	23.25
21	20.52	20.88	220	46.8	367 750	— 30 550	+22 700	10.99	21.72
22	11.34	11.70	119	42.5	293 270	— 17 000	+77 750	10.49	12.63
23	32.76	32.76	397	116.0	616 430	0	+22 700	19.52	33.74
24	33.30	33.66	417	118.8	645 310	— 49 420	—22 700	17.50	34.95
25	30.96	30.60	346	109.6	529 860	+ 45 430	+22 700	18.26	30.83
26	32.04	32.40	372	108.6	528 900	— 47 560	+22 700	15.39	33.17
27	22.68	23.40	254	52.7	477 370	— 68 010	+77 750	14.43	23.69

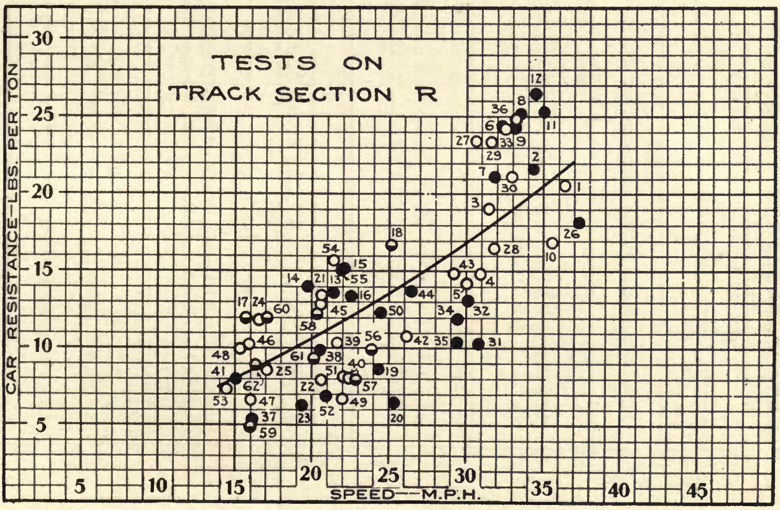

FIG. 19.

Note.—Solid dots are for runs with the wind, open circles are for runs against the wind, and circles with the lower half black are for runs in no wind.

TABLE 11

TESTS ON TRACK SECTION S.

1	2	3	4	5	6	7	8	9
							Motor Data	
Item No.	Test No.	Wind Opposing or Helping	Section Limits. — Trolley Line Pole Numbers	Grade — Rise or Fall Over Section — + Up — Down	Length of Section	Time to Run Over Section	Number in Use and Connection *	Efficiency of Motors and Gears
		O or H		Feet	Feet	Sec's.		%
1	119	H	37–29	+0.76	1 057	25.9	4 M	68.3
2	119	H	12– 4	—3.40	1 054	21.9	"	60.4
3	120	O	29–37	—0.76	1 057	22.4	"	80.2
4	120	O	4–12	+3.40	1 054	21.8	"	60.1
5	120	O	29–36	—0.54	928	20.7	"	76.0
6	119	H	37–29	+0.76	1 057	21.1	"	85.1
7	119	H	12– 4	—3.40	1 054	19.1	"	67.2
8	120	O	29–37	—0.76	1 057	26.6	"	70.4
9	119	H	12– 4	—3.40	1 054	21.6	"	63.4
10	120	O	29–37	—0.76	1 057	25.0	"	71.0
11	120	O	4–12	+3.40	1 054	26.0	"	67.8
12	119	H	12– 4	—3.40	1 054	23.0	2 M	73.1
13	120	O	29–37	—0.76	1 057	27.5	"	84.7
14	119	H	12– 4	—3.40	1 054	26.7	"	74.3
15	119	H	12– 4	—3.40	1 054	27.3	4 S	70.5
16	119	H	37–29	+0.76	1 057	30.9	"	77.2
17	120	O	29–37	—0.76	1 057	35.1	"	74.9
18	120	O	4–12	+3.40	1 054	35.0	"	72.0
19	119	H	12– 4	—3.40	1 054	28.2	"	67.8
20	119	H	37–29	+0.76	1 057	33.9	"	79.3
21	120	O	4–12	+3.40	1 054	31.7	"	76.8
22	119	H	12– 4	—3.40	1 054	26.9	"	69.9
23	119	H	12– 4	—3.40	1 054	21.0	4 M	63.3
24	120	O	29–37	—0.76	1 057	24.1	"	78.1
25	119	H	12– 4	—3.40	1 054	19.5	"	68.7
26	120	O	29–37	—0.76	1 057	26.7	2 M	82.8
27	120	O	4–12	+3.40	1 054	28.0	"	84.8
28	119	H	12– 4	—3.40	1 054	21.8	"	80.8
29	120	O	4–12	+3.40	1 054	27.7	"	84.9
30	119	H	12– 4	—3.40	1 054	25.6	4 S	64.6
31	120	O	4–12	+3.40	1 054	31.3	"	71.9
32	122	H	29–37	—0.76	1 057	34.3	"	68.7
33	122	H	4–12	+3.40	1 054	32.0	"	70.7
34	122	H	29-37	—0.76	1 057	36.9	"	70.2
35	121	O	12– 4	—3.40	1 054	21.6	4 M	72.5
36	122	H	29–37	—0.76	1 057	25.0	"	73.6
37	121	O	12– 4	—3.40	1 054	22.5	"	62.2
38	122	H	29–37	—0.76	1 057	38.5	4 Sw	67.0
39	121	O	37–29	+0.76	1 057	35.8	"	72.6
40	121	O	12– 4	—3.40	1 054	35.7	"	56.0
41	122	H	29–37	—0.76	1 057	42.5	4 S	68.8
42	121	O	12– 4	—3.40	1 054	18.6	4 M	80.9
43	122	H	4–12	+3.40	1 054	20.9	"	82.7
44	121	O	12– 4	—3.40	1 054	18.9	"	66.6
45	121	O	37–29	+0.76	1 057	19.1	"	82.3

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

Table 11 (Continued)

Tests on Track Section S.

10	11	12	13	14	15	16	17	18	19
	Speed				Energy Imparted to the Car				
Item No.	At Entrance to the Section	At Exit from the Section	Average Voltage	Average Current	By the Current	By the Change in Kinetic Energy	By the Grade	Net Car Resistance	Average Speed Over the Section
	M. P. H.	M. P. H.	Volts	Amps.	Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Lbs. Per Ton	M. P. H.
1	28.05	26.98	280	95.7	349 380	+120 710	— 43 130	14.23	27.84
2	32.20	32.01	282	79.2	217 740	+ 25 000	+192 900	14.57	32.85
3	31.47	33.10	405	131.5	705 910	—215 760	+ 43 130	17.78	32.20
4	34.36	31.11	284	77.0	211 130	+436 200	—192 900	15.19	32.99
5	29.12	30.40	361	115.0	482 080	—156 180	+ 30 650	13.55	30.56
6	31.48	35.97	524	170.0	1 180 600	—620 840	— 43 130	17.23	34.15
7	37.40	37.04	354	86.6	289 940	+ 54 940	+192 900	17.98	37.62
8	26.08	26.98	300	102.0	422 600	— 97 900	+ 43 130	12.26	27.10
9	33.10	33.28	310	82.0	256 530	— 24 490	+192 900	14.21	33.27
10	27.88	28.77	316	102.0	422 170	—103 360	+ 43 130	12.07	28.81
11	28.22	26.80	284	94.0	346 860	+160 160	—192 900	10.50	27.67
12	31.11	30.40	350	52.2	226 290	+ 89 530	+192 900	17.01	31.22
13	24.62	27.32	407	94.1	657 240	—287 490	+ 43 130	13.77	26.20
14	25.89	26.25	319	57.9	270 080	— 38 480	+192 900	14.20	26.91
15	25.52	26.61	488	45.1	312 270	—116 480	+192 900	13.00	26.31
16	22.82	23.55	512	53.6	482 400	— 69 390	— 43 130	12.33	23.32
17	19.76	21.73	434	50.7	426 170	—167 560	+ 43 130	10.06	20.52
18	20.68	19.76	405	46.9	352 740	+ 76 270	—192 900	7.89	20.52
19	24.99	25.52	452	41.7	265 660	— 54 880	+192 900	13.50	25.50
20	20.30	22.11	501	58.5	580 900	—157 360	— 43 130	12.68	21.26
21	22.82	21.91	490	53.3	468 620	+ 83 440	—192 900	12.01	22.68
22	26.08	26.80	468	43.3	280 810	— 78 050	+192 900	13.23	26.72
23	33.81	33.45	308	81.6	246 270	+ 49 640	+192 900	16.35	34.24
24	29.11	30.75	370	125.0	642 430	—201 250	+ 43 130	16.15	29.92
25	36.33	36.33	356	90.0	316 350	0	+192 900	17.03	36.89
26	26.25	26.80	393	78.6	503 150	— 59 810	+ 43 130	16.22	26.72
27	24.44	24.99	417	94.4	689 070	— 55 730	—192 900	14.72	25.69
28	32.38	32.55	432	66.3	371 790	— 22 630	+192 900	18.13	33.00
29	24.62	25.18	419	95.0	689 940	— 57 170	—192 900	14.71	25.98
30	26.61	26.80	463	39.0	220 150	— 20 800	+192 900	13.12	28.10
31	22.63	21.39	454	45.8	344 890	+111 900	—192 900	8.82	23.08
32	20.48	20.48	202	49.7	348 960	0	+ 43 130	13.07	21.02
33	23.19	20.83	229	53.1	405 450	+212 970	—192 900	14.23	22.48
34	18.50	19.40	193	52.5	387 050	— 69 930	+ 43 130	12.01	19.54
35	33.09	32.91	338	104.0	406 300	+ 24 350	+192 900	20.85	33.30
36	26.98	28.05	301	116.0	473 860	—120 710	+ 43 130	13.21	28.86
37	32.55	31.66	266	81.2	222 730	+117 150	+192 900	17.81	31.98
38	17.78	18.50	174	50.0	331 000	— 53 550	+ 43 130	10.69	18.74
39	19.22	19.76	229	57.8	507 570	— 43 150	— 43 130	14.05	20.14
40	19.94	19.04	159	37.0	173 390	+ 71 920	+192 900	14.65	20.13
41	15.62	17.24	174	50.8	381 270	—109 130	+ 43 130	10.51	16.96
42	36.50	37.95	475	128.0	675 280	—221 300	+192 900	21.63	38.69
43	34.00	34.35	465	143.0	848 320	— 49 040	—192 900	20.27	34.42
44	38.68	37.78	355	85.4	281 280	+141 070	+192 900	20.57	38.08
45	38.31	38.31	505	136.0	796 440	0	— 43 130	25.12	37.75

Table 12

Tests on Track Section R.

1	2	3	4	5	6	7	8	9
							Motor Data	
Item No.	Test No.	Wind O or H	Section Limits	Grade	Length of Section	Time	No. and Connection *	Efficiency
1	125	O	14 - 4	—2.62	1 320	24.7	4 M	80.3
2	126	H	4 - 14	+2.62	1 320	26.2	4 M	78.9
3	125	O	45 - 38	—2.93	920	19.9	4 M	84.3
4	125	O	14 - 4	—2.62	1 320	29.1	4 M	73.7
5	125	O	45 - 38	—2.93	920	20.9	4 M	80.5
6	126	H	38 - 45	+2.93	920	19.4	4 M	83.8
7	126	H	4 - 14	+2.62	1 320	28.3	4 M	75.9
8	126	H	38 - 45	+2.93	920	18.7	4 M	85.1
9	126	H	4 - 14	+2.62	1 320	27.1	4 M	77.4
10	125	O	45 - 38	—2.93	920	17.6	4 M	83.8
11	126	H	38 - 45	+2.93	920	17.9	4 M	85.0
12	126	H	4 - 14	+2.62	1 320	26.1	4 M	80.2
13	126	H	38 - 45	+2.93	920	29.3	4 S	77.3
14	126	H	4 - 14	+2.62	1 320	45.6	4 S	71.4
15	126	H	4 - 14	+2.62	1 320	40.9	4 S	75.3
16	126	H	38 - 45	+2.93	920	27.8	4 S	76.3
17	128	—	4 - 14	+2.62	1 320	57.1	4 S	72.4
18	127	—	14 - 4	—2.62	1 320	35.8	4 M	62.4
19	129	H	14 - 4	—2.62	1 320	36.9	4 S	66.6
20	129	H	45 - 38	—2.93	920	24.7	4 S	73.5
21	130	O	4 - 14	+2.62	1 320	43.6	4 S	72.0
22	130	O	38 - 45	+2.93	920	30.4	4 S	63.3
23	129	H	14 - 4	—2.62	1 320	46.5	4 S	38.0
24	130	O	4 - 14	+2.62	1 320	54.4	4 S	72.5
25	130	O	38 - 45	+2.93	920	36.8	4 S	70.7
26	129	H	14 - 4	—2.62	1 320	24.1	4 M	76.0
27	130	O	4 - 14	+2.62	1 320	29.4	4 M	82.5
28	130	O	38 - 45	+2.93	920	19.7	4 M	82.9
29	130	O	38 - 45	+2.93	920	19.8	4 M	83.2
30	130	O	4 - 14	+2.62	1 320	27.3	4 M	84.0
31	129	H	45 - 38	—2.93	920	20.3	4 M	72.7
32	129	H	14 - 4	—2.62	1 320	29.9	4 M	46.7
33	130	O	4 - 14	+2.62	1 320	27.7	4 M	82.7
34	129	H	45 - 38	—2.93	920	21.3	4 M	45.8
35	129	H	14 - 4	—2.62	1 320	30.6	4 M	65.4
36	130	O	4 - 14	+2.62	1 320	27.1	4 M	83.4
37	129	H	27 - 24	—0.26	372	16.7	4 S	49.5
38	142	H	1 725 -1 730	+1.63	519	17.2	4 S	74.0
39	141	O	1 741 -1 737.5	—1.90	338	10.6	4 S	55.0
40	141	O	1 730 -1 725	—1.63	519	15.8	4 S	65.4
41	142	H	1 737.5-1 741	+1.90	338	15.3	4 S	71.4
42	141	O	1 730 -1 725	—1.63	519	13.5	4 M	44.0
43	141	O	1 730 -1 725	—1.63	519	12.1	4 M	43.0
44	142	H	1 737.5-1 741	+1.90	338	8.7	4 M	69.4
45	141	O	1 741 -1 737.5	—1.90	338	11.2	4 S	69.3
46	141	O	1 730 -1 725	—1.63	519	22.2	4 S	53.6
47	141	O	1 741 -1 737.5	—1.90	338	14.4	4 S	66.5
48	141	O	1 730 -1 725	—1.63	519	23.0	4 S	43.0
49	141	O	1 730 -1 725	—1.63	519	16.1	4 S	60.3
50	142	H	1 737.5-1 741	+1.90	338	9.4	4 M	77.7
51	141	O	1 730 -1 725	—1.63	519	16.0	4 S	49.6
52	142	H	1 737.5-1 741	+1.90	338	11.0	4 M	63.1
53	141	O	1 730 -1 725	—1.63	519	24.4	4 S	55.1
54	141	O	1 730 -1 725	—1.63	519	16.5	4 S	58.4
55	142	H	1 737.5-1 741	+1.90	338	10.5	4 M	73.2
56	141	O	1 730 -1 725	—1.63	519	14.8	4 M	47.8
57	153	—	1 730 -1 725	—1.63	519	15.5	4 S	41.0
58	153	—	1 730 -1 725	—1.63	519	17.4	4 S	31.0
59	153	—	1 741 -1 737.5	—1.90	338	14.4	4 S	42.1
60	153	—	1 730 -1 725	—1.63	519	15.7	4 S	33.5
61	153	—	1 730 -1 725	—1.63	519	17.5	4 S	43.4
62	153	—	1 741 -1 737.5	—1.90	338	14.1	4 S	37.5

*S=Series-multiple. M=Multiple. Sw=Switching. C=Coasting.

Tablf 12 (Continued)

Tests on Track Section R.

10	11	12	13	14	15	16	17	18	19
Item No.	Speed		Average Voltage	Average Current	Energy Imparted to the Car			Net Car Resistance	Average Speed
	Entrance	Exit			By the Current	By the Kinetic Energy	By the Grade		
1	35.29	36.52	431	128.4	809 490	—182 840	+150 260	20.53	36.43
2	34.73	33.11	380	127.7	739 860	+227 500	—150 260	21.59	34.35
3	29.16	33.67	441	168.7	920 480	—586 560	+168 040	19.03	31.50
4	29.68	30.96	321	112.2	569 730	—160 670	+150 260	14.78	30.92
5	26.80	30.60	365	145.2	657 630	—451 510	+168 040	14.18	30.00
6	32.02	30.78	387	139.7	648 150	+161 200	—168 040	24.31	32.31
7	32.58	30.22	340	119.2	642 040	+306 800	—150 260	21.10	31.81
8	32.58	34.01	490	178.8	1 028 200	—197 110	—168 040	25.13	33.51
9	35.47	32.75	361	122.6	684 670	+384 110	—150 260	24.27	33.21
10	32.76	36.52	480	156.2	815 570	—539 220	+168 040	16.84	35.61
11	34.38	35.28	496	173.2	964 010	—129 780	—168 040	25.25	35.02
12	36.19	33.82	397	132.1	809 540	+343 460	—150 260	26.49	34.50
13	20.32	21.41	264	70.3	620 020	— 94 160	—168 040	13.56	21.39
14	21.22	19.61	205	55.1	542 410	+136 070	—150 260	13.96	19.74
15	21.78	22.31	262	64.8	771 350	— 48 370	—150 260	15.13	22.00
16	20.88	21.41	266	68.1	566 770	— 46 400	—168 040	13.36	22.55
17	15.42	16.31	182	59.8	663 740	— 58 600	—150 650	11.98	15.77
18	27.48	25.51	193	84.0	267 060	+216 610	+150 650	16.71	25.12
19	23.78	25.58	214	46.4	359 960	—183 920	+150 260	8.62	24.39
20	22.13	26.29	265	59.0	418 670	—417 000	+168 040	6.43	25.38
21	21.22	19.97	214	55.6	551 010	+106 580	—150 260	13.40	20.63
22	20.52	18.54	175	43.4	216 130	+160 100	—168 040	7.89	20.62
23	18.54	18.54	112	29.4	85 830	0	+150 260	6.24	19.35
24	15.29	16.02	185	59.8	643 660	— 47 310	—150 260	11.78	16.54
25	18.17	18.00	180	55.1	380 700	+ 12 730	—168 040	8.54	17.04
26	37.98	38.18	376	112.2	569 890	— 31 740	+150 260	18.19	37.35
27	29.70	30.08	387	156.4	1 082 800	— 47 020	—150 260	23.39	30.61
28	30.79	32.07	413	154.5	768 540	—166 550	—168 040	16.45	31.82
29	31.51	31.51	413	156.2	783 740	0	—168 040	23.34	31.66
30	31.32	33.49	445	164.7	1 239 500	—291 120	—150 260	21.08	32.97
31	28.07	30.25	298	111.7	362 330	—263 180	+168 040	10.13	30.90
32	29.71	27.57	162	54.2	90 420	+253 740	+150 260	13.06	30.10
33	32.78	32.95	432	149.3	1 089 700	— 23 130	—150 260	24.21	32.50
34	29.52	28.81	158	152.3	59 450	+ 85 730	+168 040	11.87	29.45
35	27.72	28.28	232	89.3	305 820	— 64 920	+150 260	10.33	29.41
36	33.68	34.02	434	157.2	1 137 300	— 47 650	—150 260	24.81	33.21
37	14.76	14.76	99	34.4	41 520	0	+ 14 910	5.29	16.18
38	19.32	19.86	248	61.3	285 450	— 44 110	— 94 210	9.81	20.58
39	20.95	21.67	173	36.6	54 430	— 63 980	+109 820	10.27	21.72
40	20.58	21.85	202	45.1	138 850	—112 350	+ 94 210	8.05	22.40
41	15.36	14.64	149	59.4	142 600	+ 45 040	—109 820	7.97	15.05
42	25.62	25.28	139	50.2	30 570	+ 36 080	+ 94 210	10.72	26.20
43	29.05	28.32	176	59.1	39 910	+ 87 320	+ 94 210	14.77	29.22
44	26.52	25.28	246	100.0	109 540	+133 920	—109 820	13.68	26.49
45	18.60	19.87	202	50.6	117 300	—101 820	+109 820	12.83	20.58
46	15.18	15.36	109	36.5	69 830	— 11 460	+ 94 210	10.17	15.94
47	13.92	16.08	129	49.2	89 620	—135 110	+109 820	6.58	16.00
48	15.90	15.54	84	24.8	30 390	+ 23 890	+ 94 210	9.90	15.37
49	20.78	21.83	170	40.7	99 090	— 93 280	+ 94 210	6.66	21.98
50	26.35	26.35	298	143.0	229 520	0	—109 820	12.25	24.51
51	22.02	22.38	155	33.6	60 990	— 33 330	+ 94 210	8.12	22.10
52	21.12	20.04	191	85.6	83 700	+ 92 680	—109 820	6.81	20.96
53	13.02	14.28	117	37.5	87 010	— 71 720	+ 94 210	7.30	14.50
54	21.12	20.58	169	39.1	93 950	+ 46 950	+ 94 210	15.67	21.42
55	22.57	21.49	236	118.0	157 860	+ 99 210	—109 820	15.08	21.92
56	23.47	23.47	159	65.1	54 160	0	+ 94 210	9.89	23.90
57	21.57	21.92	223	27.4	57 270	— 31 740	+ 94 380	7.98	22.82
58	19.94	19.03	94	20.5	15 330	+ 73 940	+ 94 380	12.22	20.34
59	14.71	16.16	113	30.8	31 120	— 93 330	+110 010	4.88	16.00
60	22.11	21.39	115	22.5	20 070	+ 65 300	+ 94 380	11.96	17.12
61	19.94	19.94	131	31.0	45 490	0	+ 94 380	9.31	20.22
62	16.16	16.70	74	24.1	13 850	— 37 000	+110 010	8.88	16.33

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